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Summary of U.S. Environmental Protection Agency's Ohmsett Testing, 1974-1979

Mason and Hanger-Silas Mason Co., Inc.
Leonardo, NJ

Prepared for

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Research to evaluate and improve the ability to respond effectively to spills of floating oil and hazardous materials has been performed at the U.S. Environmental Protection Agency's OHMSETT test facility since August 1974. Over 84 devices were tested under 73 research programs from August 1974 through November 1979. This summary report describes results of tests on commercial, prototype, and model devices designed to control, contain, recover, detect or measure floating oil and hazardous material spills. It also describes research into oil weathering, environmental monitoring, spill behavior and chemical treating agents. Conclusions, data tables, and lists of available reports and films are included.

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

This user's guide contains summary data on the more than 80 oil and hazardous materials spills cleanup devices evaluated at EPA's OHMSETT test facility from the time operations began in August 1974 through December 1979. This volume will be of interest to all those concerned with commercial, prototype, or model devices designed to control, recover, detect or measure spilled floating oil or hazardous materials.

Francis T. Mayo, Director
Municipal Environmental Research
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PREFACE

The U.S. Environmental Protection Agency's Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT) has been evaluating devices to combat oil spills since 1974. During the 1974 through 1979 period, 56 separate OHMSETT research reports have been published by various public and private organizations. This summary report provides a single source of data and references for all OHMSETT research through 1979. Lists of test devices have been included in the Appendices to assist readers in finding specific devices or manufacturers.

OHMSETT research programs are assigned Job Order numbers to separate costs for each program. Job Orders have been assigned sequentially at the conception of a program and are used in this report for organization only. The Job Order number of a program does not reflect on the time sequence in which each program was executed. We editors have compiled the data tables and conclusions sections for each Job Order from the respective individual reports. Data and conclusions found in this report are therefore the contribution of the individual report authors.

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ABSTRACT

Research to evaluate and improve the ability to respond effectively to spills of floating oil and hazardous materials has been performed at OHMSETT since 1974. Over 84 devices were tested under 73 research programs from 1974 through 1979. This report describes results of tests on commercial, prototype, and model devices designed to control, contain, recover, detect or measure floating oil and hazardous material spills. It also describes research into oil weathering, environmental monitoring, spill behavior and chemical treating agents. Conclusions, data tables, and a list of available reports and films are included.

This report was submitted under Job Order No. 74 in partial fulfillment of Contract No. 68-03-2642, by Mason & Hanger-Silas Mason Co., Inc. with the sponsorship of the U.S. Environmental Protection Agency. This report covers the period of June 1, 1974, through December 31, 1979. Work on this report was completed December 1, 1980.

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ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

cm	--centimeter
cSt	--centistokes
m^3	--cubic meters
CPM	--cycles per minute
ft	--feet
gal	--gallons
gpm	--gallons per minute
H/L	--height to length steepness ratio
in	--inch
I.R.	--infrared
kt	--knot
m	--meter
min	--minutes
m/min	--meters per minute
m/s	--meters per second
m^2/s	--meters squared per second
mm	--millimeters
mV/m/s	--millivolts per meter per second
OHMSETT	--Oil and Hazardous Materials Simulated Environmental Test Tank
lbs	--pounds
lbs/ft	--pounds per foot
secs	--seconds
ft^2	--square feet
m^2	--square meters
DOP	--dioctyl phthalate
H	--height
L	--length
P	--period
m^3/hr	--cubic meters per hour
$^{\circ}C$	--degrees Centigrade
$^{\circ}F$	--degrees Fahrenheit
IFT	--interfacial tension
RE	--recovery efficiency
TE	--throughput efficiency
HC	--harbor chop
no.	--number
max.	--maximum
IAG	--interagency agreement
ORR	--oil recovery rate
avg.	--average

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NTIS	--National Technical Information Service
fpm	--feet per minute
cp	--centipoise
HM	--hazardous materials
kPa	--kilopascals
rec.	--recovery
ASTM	--American Society for Testing and Materials
kg/cm^2	--kilograms per square centimeter
rpm	--revolutions per minute
kn	--kilonewtons
N	--newtons
N/m^2	--newtons per square meter
kg/cm^2	--kilograms per square centimeter
ppm	--parts per million
mpa	--mega pascals
RMS	--root-mean-square
N/A	--not applicable
Fwd.	--forward
Ext.	--extension
Stbd.	--starboard
spd.	--speed
thk.	--thickness
dist.	--distribution
MT	--metric ton
dm	--decimeters

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LIST OF CONVERSIONS

METRIC TO ENGLISH

To convert from	to	Multiply by
Celsius	degree Fahrenheit	$t_c = (t_F-32)/1.8$
joule	erg	1.000 E+07
joule	foot-pound-force	7.374 E-01
kilogram	pound-mass (lbm avoir)	2.205 E+00
metre	foot	3.281 E+00
metre	inch	3.937 E+01
metre^2	foot^2	1.076 E+01
metre^2	inch^2	1.549 E+03
metre^3	gallon (U.S. liquid)	2.642 E+02
metre^3	litre	1.000 E+03
metre/second	foot/minute	1.969 E+02
metre/second	knot	1.944 E+00
metre^2/second	centistoke	1.000 E+06
metre^3/second	foot^3/minute	2.119 E+03
metre^3/second	gallon (U.S. liquid)/minute	1.587 E+04
newton	pound-force (lbf avoir)	2.248 E-01
watt	horsepower (550 ft lbf/s)	1.341 E-03
Kilopascals	pounds/in^2	

ENGLISH TO METRIC

centistoke	metre^2/second	1.000 E-06
degree Fahrenheit	Celsius	$t_c = (t_F-32)/1.8$
erg	joule	1.000 E-07
foot	metre	3.048 E-01
foot^2	metre^2	9.290 E-02
foot/minute	metre/second	5.080 E-03
foot^3/minute	metre^3/second	4.719 E-04
foot-pound-force	joule	1.356 E+00
gallon (U.S. liquid)	metre^3	3.785 E-03
gallon (U.S. liquid)/minute	metre^3/second	6.309 E-05
horsepower (550 ft lbf/s)	watt	7.457 E+02
inch	metre	2.540 E-02
inch^2	metre^2	6.452 E-04
knot (international)	metre/second	5.144 E-01
litre	metre^3	1.000 E-03
pound force (lbf avoir)	newton	4.448 E+00
pound-mass (lbm avoir)	kilogram	4.535 E-01
pounds/in^2	Kilopascals	

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ACKNOWLEDGMENTS

The contents of this report represents six years of cumulative effort by people from U.S. EPA, Mason & Hanger-Silas Mason Co., Inc., other government agencies, and subcontractors. Special recognition is given to the U.S. EPA OHMSETT Project Officers, Mr. F.J. Freestone, (1974 to 1976), Mr. J.S. Farlow (1976 to 1979) and Mr. R.A. Griffiths (1979 to present). Their ideas and direction not only catalyzed the construction of OHMSETT, but its continued operation and expanding scope. The writers are deeply indebted to the authors of the many test reports published from OHMSETT work. The conclusion sections for the most part came directly from the test reports.

I also thank the many Mason & Hanger-Silas Mason Co., Inc. employees who contributed to test programs described in this report. Special thanks go to Mr. J.D. Moran for his patient research and assembly of the many data tables reported and to Mr. D.C. Gates for his editorial review of the entire report and data.

Support, both creative and financial, by the many OHMSETT customers is gratefully acknowledged. OHMSETT has and continues to exist to serve their needs.

SECTION 1

INTRODUCTION

FACILITY HISTORY

OHMSETT is designed to evaluate the performance of equipment to detect, monitor, and cleanup oil and floating hazardous material spills under environmentally safe conditions. The heart of OHMSETT is the world's largest tow/wave tank designed to work with oil and hazardous materials. Mason & Hanger-Silas Mason Co., Inc. operates OHMSETT for the U.S. Environmental Protection Agency (EPA) using a full-time staff of 21 with temporary personnel and specialized subcontractors added as required. Normally, tank tests are performed from April through November with most programs lasting 10 to 14 days. A study is in progress to accommodate cold weather and ice testing by lengthening the test season.

Many of today's commercially available spill cleanup devices have been tested at OHMSETT either as off-the-shelf equipment or as equipment still in development. Sixty-two Job Orders have been completed from 1974 thorough 1979 with technical reports available for many of the programs. Direct comparison between spill cleanup devices is avoided, because each device is intended for different, specific conditions and the maintenance-deployment-retrieval-logistics are generally not examined in OHMSETT test programs.

GENERAL FACILITY LAYOUT

OHMSETT is located on the Naval Weapons Station (NWS)-Earle waterfront in Leonardo, New Jersey. The outdoors, above-ground test tank is built of concrete and measures 203 m long and 20 m wide inside. The tank is normally filled with brackish water from nearby Sandy Hook Bay, but fresh water may also be used. Support services such as heavy lifting, trucks, material handling, fire department, medical, repair and fabrication are available from NWS-Earle.

OHMSETT has one permanent and three removable bridges which can be used in various combinations for testing. These are called the main bridge, auxiliary bridge, video bridge, and vacuum bridge. In one commonly used configuration, the main bridge (permanent) is attached to an auxiliary bridge by the video bridge. A third bridge normally used for vacuuming the tank bottom, may be utilized for advance oil distribution. The bridges all ride on the same pair of rails and are cable-driven by two 373 kilowatt variable speed motors. The device to be tested is either supported from the bridges or floated. Positioning of the bridges, loadings, and instrumentation mountings, are flexible for special or unusual arrangements to interface the test device with the facility.

The maximum distance between the main and auxiliary bridges is limited to the 22.2 meter length of the video bridge. The video bridge can be removed entirely to permit even greater distances. Changing the relative location of the bridges (such as moving the auxiliary bridge in front of the main) is a major effort involving two 63 metric ton cranes and a large work crew.

The vacuum bridge, normally used to clean sediment from the tank floor, can be used for special oil distribution ahead of the main bridge manifold system. It can be self-propelled at speeds to 4 knots or clamped to the drive cables.

At the south end of the tank is the wave generator, which consists of two rectangular flaps, pivoted at the bottom of the tank, whose top edges are rocked back and forth through mechanical linkages by an electrohydraulic power system. The system can generate either regular waves or confused sea (harbor chop) conditions. A beach is located at the opposite end of the test tank from the wave generator. The beach is used to reduce wave reflection when regular waves are desired for testing. Beach sections also can be lowered to encourage waves to reflect off the north tank wall. Interaction between the incident and reflected waves produces harbor chop waves suitable for use in testing.

Water clarity for photo/video data taking is maintained by continuously circulating the tank water through a 450 m^3/hr pressure-leaf filter. The filter is located on a concrete pad at the northeast corner of the test tank. Diatomaceous earth filter-aid of various pore sizes coats the filter leaves to remove particulates down to five microns in size. An electrolytic chlorinator is used to control biological activity. Ancillary systems are installed to handle used diatomaceous earth and the material removed from the tank water. Oil content in the water is reduced below one part per million prior to emptying the tank at the end of each test season.

OHMSETT has the capability of storing up to 416 m^3 of test fluids in permanent and mobile tanks. Because of the variety of test fluids used, only 76 m^3 of any one fluid is generally stored at any one time. Test fluids are reprocessed to remove particulates and water prior to reuse in testing. Reprocessing capability depends on oil type, ambient temperature, water and sediment content, and quantities used per day. A mixture of settling, heating, filtering, and vacuum distillation may be used to treat used test fluids.

FACILITY CAPABILITIES

Device Sizes

The maximum area between the three bridges is 22 m long and 19 m wide. The water depth is 2.4 m. Test devices up to 17.7 m long, 4.3 m beam, and 1.6 m draft displacing 39 metric tons have been tow-tested at OHMSETT. Devices this size, require subcontractor assistance for placing the device in the test tank and must be carefully coordinated. OHMSETT has cranes able to lift up to 6.5 metric tons into and out of the tank. Support services available from Naval Weapons Station Earle include cranes able to place up to 18 metric tons in the tank. Test devices are attached to the main and auxiliary bridges with large ropes to provide a soft, flexible connection for towing. This minimizes any sudden shocks on the test device or the bridges during tow start and stop.

OHMSETT bridges have been analyzed for structural load limits. The main bridge has a demonstrated capability to support 1.2 metric tons/m^2 static load in the clear area east of the bridge house. Load limits for the vacuum bridge are 4.3 metric tons concentrated load plus 4.1 kg per lineal meter. Video bridge limits are 900 kg concentrated load, and the auxiliary bridge will hold 180 kg concentrated load plus 72 kg per lineal meter (See Figures 1-5 on pp. 12-16).

Water Current and Bridge System

Relative motion between the water surface and the test device is produced by towing the device from one end of the tank to the other using the bridges. Test devices will generally be placed between the main and the auxiliary bridges . Soft attachments are made from the test device to each bridge. Test runs are usually made from North to South using the main bridge to tow the test device. The bridges are moved by cables and two electric winches, capable of speeds to 6.5 knots with a drag force of up to 151 KN. Skimming booms on the main and auxiliary bridges are used after each test to capture any test fluid remaining on the tank surface. The test device is towed back to the North tank end by the auxiliary bridge, with the two skimming booms cleaning the tank surface for the next test.

The bridge system is capable of accelerating most test configurations from 0 to 6.5 knots in a distance of 15.2 m over a period of 8 seconds. Deceleration from 6.5 to 0 knots (other than emergency stops) can be done in a distance of 9.1 m over a period of 7 seconds. Maximum test times range from 300 seconds at 1 knot to 46 seconds at 6.5 knots. Since performance data is collected during steady state device operation, data will usually be collected for half of these test times. These are maximum performance figures; the drive system can also be accelerated or decelerated to maximum speed over greater distances.

There will be no structural metal cutting or welding to the bridges to accommodate user test devices. Normally, test devices will be clamped to the bridge(s) or attached with ropes. Equipment weighing in excess of 2.3 metric ton will not be set on or attached to any bridge without seeking competent engineering advise at the user's expense. Placard limitations will not be exceeded without the written approval of a qualified structural engineer.

Fluids Handling

The OHMSETT main bridge has three separate distribution manifolds to provide the needed versatility for testing. One is a weir/splash plate that can produce slicks up to 4.6 m wide. The second system is a series of twenty spray nozzles in a row that can lay a slick up to 18 m wide across the OHMSETT tank. The third manifold system on the main bridge is an overflow-weir type that can distribute a slick up to 9.1 m wide. Each of these systems has a capacity of up to 230 m^3/hr of light oil at 16°C, is powered by up to four pumps on the main bridge, and is supplied from four 2.3 m^3 oil storage tanks. A greater pump rate with a larger reservoir of fluid can be arranged if ample notice is given. The flow is measured with flowmeters, giving total flow volume and flow rate. The test fluid is distributed far enough ahead of the device under test to ensure that the test fluid is floating on the water surface when the test device reaches it.

The slick width is selected by matching the width of the skimmer inlet in order to facilitate accurate calculations of encounter rate and to conserve test fluids. The distribution rate is based on the required slick thickness at the test tow speed. Initial acceleration at the start of the test and deceleration at the end may account for as much as one-third the tank length.

In order for test runs to be comparable, the tank surface must be cleared of test fluid before each run is begun. This is usually done by lowering a skimming boom beneath the main and auxiliary bridges after each test and sweeping the test fluid to the north end of the tank while the bridge returns at one-half knot to the starting point. The test fluid is left in a storage area until it is pushed using a fire hose stream into a sluice gate to be refurbished.

Current test fluids used at OHMSETT include those listed below (see Table 1) and #2 fuel oil. Circo oils exhibit good stability for reprocessing and reuse. Naphtha, n-Octanol, and Dioctyl Phthalate (DOP) are used to simulate floating hazardous materials. Test oils used at OHMSETT are selected to span a typical broad range of physical properties.

TABLE 1. TEST FLUID SPECIFICATIONS SHEET

Oil	Interfacial Tension (dynes/cm)	Surface Tension (dynes/cm)	Viscosity @28.8°C (cSt)	Specific Gravity
Naphtha	10	25	5	0.800
Octanol	8	28	15	0.860
Dioctyl Phthalate	15	28	65	0.980
Circo XXXX Light	27	33	9	0.890
Circo XX Light	27	33	24	0.907
Circo Medium	26	33	200	0.927
Circo Heavy	26	34	700	0.936
Circo X Heavy	26	34	1300	0.940
Circo XX Heavy	26	35	4000	0.950

The values on the table normally vary as much as 10-15% from those listed. A surfactant may be added to a test oil to lower the interfacial tension (IFT) if desired. Fluids of differing viscosities may be obtained by blending stock fluids. Adding modifiers or blending will cause a test fluid to become specific to the user who requested the modification, i.e., not necessarily useable by the next tank user. All lube oils, octanol and dioctyl phthalate (DOP) may be vacuum distilled to facilitate reuse. However, the properties of IFT and viscosity are lowered by the process (IFT by 50% on the first pass, viscosity by 10% on the first pass).

It is generally too expensive to use new test fluids for each test. Used oil or hazardous materials are refurbished to remove dirt, debris, and water. One or more of the following processes are involved in this operation:

1. Settling - the used fluid is allowed to separate by gravity from the water by remaining in a tank, generally overnight.

2. Coalescence - emulsified fluid is filtered and separated further into heavier (water) and lighter (oil or hazardous material) constituents by passing through a liquid/liquid/solids filter/coalescer. The lighter constituent continues through processing while the water is discharged back into the test tank.

3. Heating - the fluid is heated in a series of electrical coil heaters where water is flashed off as vapor. In addition, the elevated temperatures encourage separation of emulsions.

4. Vacuum distillation - the fluid is again filtered and then enters a vacuum distillation unit. Reclamation is accomplished in a continuous cycle operation by heating the contaminated fluid as a thin film (increasing its surface exposure) and applying a vacuum. The maximum rate of reclamation is 1.13 m^3/hour.

Step (2) is optional depending upon the fluid's physical properties. The rate of fluid refurbishment varies. The viscosity, degree of emulsification, debris, dirt contamination, and desired purity of the finished product all affect the rate of refurbishment.

For estimating purposes, about 0.75 m^3/hr of No. 2 fuel oil or about 0.57 m^3/hr of heavier lube oil can be processed to bring the water content below 0.2%. A test tank user who chooses to use a stock OHMSETT oil, when available, will be responsible for the cost of returning the oil to its original condition and the cost of oil replacement due to shrinkage through use and reprocessing. Users who authorize purchase of new test oils and desire reprocessing before reuse will also be assessed reprocessing costs. Reprocessing is done for approximately 38% of new oil cost. Spent test fluids usually settle before reprocessing; therefore, the tank user must be prepared for at least a 3-day lag time in fluid reprocessing.

Regardless of the test fluid desired by the user, specifications and tolerances on all fluid properties that are to be controlled throughout the duration of testing should be provided by the user and approved by the OHMSETT Test Engineer. No test fluid will be permitted to be used unless it can be effectively removed from the tank water.

Lab Analysis

Capabilities of the OHMSETT laboratory are focused on obtaining physical properties of the test fluids, analyzing recovered fluid from cleanup devices for oil content and analyzing test tank water for compliance with OHMSETT's NPDES permit.

Sampling for test fluid physical properties is done from the main bridge oil distribution system every time test fluids are added. A one-liter sample is analyzed for surface tension, interfacial tension against tank water, specific gravity, bottom solids, water content, and viscosity versus temperature.

Fluid recovered by test devices is measured and analyzed to determine recovery (RE) and throughput efficiencies (TE). Recovery efficiency is the test fluid percentage in the recovered fluid volume. Throughput efficiency is test fluid recovered divided by test fluid distributed expressed as a percentage. In order to determine volume of test fluid recovered, recovered fluid tank volume is measured and samples are taken. Centrifuge analysis provides the percent of test fluid in the total fluid recovered (RE). Multiplying the total volume of fluid recovered by the percentage of test fluid in the sample determines the volume of test fluid recovered. Results are provided to the user and the OHMSETT Test Engineer.

In order to comply with Federal discharge regulations, OHMSETT tank water is analyzed weekly for salinity, conductivity, temperature, pH, and suspended solids. Prior to draining the tank for maintenance, oil content in the water is determined by infrared (IR) spectroscopy. Tank water is not drained until all discharge permit conditions are met.

The table below gives estimates of the time required for typical OHMSETT lab tests. These numbers can be used for estimating lab man-hours and turnaround times. The following assumes an analysis which starts from scratch (therefore instrument warmup and calibration times are included):

TABLE 2. TIME REQUIRED FOR OHMSETT LAB TESTS

Analysis	Preparation time hours	Analysis time	No. of samples per analysis
oil in water (Beckman IR-33)	4.0	4.0	4
water in oil (Centrifuge)	.25	1.0	4

(Continued)

TABLE 2. (Continued)

Analysis	Preparation time hours	Analysis time	No. of samples per analysis
oil surface tension (DuNouy Ring)		0.25	1
oil/water interfacial tension (DuNouy Ring)		0.25	1
viscosity (Brookfield LU & Saybolt)	0.5	0.25	1
specific gravity (Hydrometer)		0.25	1
gas chromatogram (Varian 1400 w/FID)	12.0	4.0	Depends on types of samples
Water salinity, conductivity & temperature (YSI-SCT meter)	0.5	0.25	1
pH (Fisher Model 120 pH meter)	0.2	0.25	1

Waves

A wave generator is available for use during tests at OHMSETT. The wave generator drive unit includes a variable-speed hydrostatic drive, reduction gear and flywheel with adjustable eccentric (Scotch yoke). The drive unit is coupled to two flap-type wave generators by shafts and linkages. The drive unit's manual controls provide for variation of frequency while the unit is operating.

To produce evenly propagating or breaking waves with minimum reflections (regular waves), the wave flaps are aligned with each other, and a wave absorber beach at the North end of the tank is used to dampen the oncoming waves. The reflection coefficient of the beach varies from approximately 20% to 50%, depending on the dimensions of the incident wave. To produce an uneven, confused sea state (harbor chop), the beach is lowered to allow reflection of the waves. Fifteen minutes from start of the wave generator is required before a steady state condition is achieved throughout the tank. Half an hour may be required to completely dampen out the waves when the beach is not in use.

Wave height data are measured with an acoustic transponder probe, recorded on magnetic tape, and statistically analyzed. OHMSETT has the on-site computing capabilities necessary to yield a power spectral density, significant wave heights, and lengths. The desired wave condition is selected from wave study data (see Tables 3 and 4) prior to beginning each test. Regular waves can be produced with periods of 1 to 6 seconds, lengths to 45 m and significant heights to 0.45 m. Confused sea or harbor chop conditions can be produced with significant heights to 0.54 m. Waves can be measured with the sonic probe to determine wave characteristics during a test.

About 15 minutes is required to lower the beach for the harbor chop condition and about 30 minutes to raise the beach to convert from harbor chop to regular waves. During these conversions, the bridge cannot be moved. Changing the speed of the wave generator is done by adjusting a potentiometer on the control panel. Changing the stroke (wave height) is a mechanical adjustment requiring approximately 15 minutes.

Data Processing

OHMSETT test programs generate quantitative and qualitative data from three sources: test conditions, lab results, and observation. Test conditions include device operational conditions, wave condition, tow speed, test fluid distribution rate, and weather. Lab results contain values for test fluid physical properties and oil/water composition of skimmer recovery. Observations include notes taken by test personnel and photo/video output.

Quantitative data is processed by an on-site computer to obtain performance results (throughput efficiency, recovery efficiency, and oil recovery rate). Computer generated graphics produce report quality data tables, charts, and graphs. Staff draftsmen provide blueprints and figures needed for device modifications and reports. Original data is retained in OHMSETT files with a copy provided to the U.S. EPA, the customer, and others as requested by the customer.

Photo/Video

One of the benefits of testing at OHMSETT is the under and above water black and white and color video equipment which permits an immediate qualitative analysis of a test run. On the site, there are eight video cameras, four tape decks, twelve monitors, and a special effects generator. The capability of duplicating tapes exists; however, duplication and collection of video data require the same equipment and cannot be done simultaneously. Video formats are 1" IVC, 3/4" U-matic, and ½" VHS, in either black and white or color.

The underwater video camera is protected in a stainless steel, pressurized case. It can be submerged up to 2.1 m and positioned anywhere within the bridges. The system includes remote positioning and function controls which ensure a choice of views without repositioning the camera strut. All cameras can be used in a studio environment or outdoors, protected from the elements with appropriate enclosures and remote positioning. A special effects generator allows smooth switching from camera to camera as well as split screen and other graphic aids.

TABLE 3. WAVE STUDY - REGULAR WAVES (JO 61-3)

Test no.	Stroke in.	CPM	Length m	H(1/3) m	H(1/10) m	H(max.) m	Reflection %
1	1.5	32	5.48	0.136	0.181	0.302	32
2	1.5	44	2.9	0.321	0.466	0.626	29
4	3	17	19.22	0.19	0.199	0.207	45
5	3	26	8.31	0.192	0.212	0.242	35
6*	3	30	6.24	0.264	0.322	0.421	52
7	3	45	2.77	0.193	0.261	0.322	38
8	4.5	15	24.19	0.136	0.152	0.162	59
9	4.5	26	8.31	0.255	0.283	0.337	50
10	4.5	40	3.51	0.22	0.271	0.337	32
11	6	15	24.19	0.288	0.3	0.312	47
12	6	20	14.02	0.352	0.388	0.438	59
13	6	24	9.75	0.337	0.399	0.471	42
14	7.5	18	17.23	0.35	0.39	0.405	47
15	7.5	22	11.6	0.372	0.413	0.451	49
16	9	15	24.19	0.288	0.327	0.438	46
17	9	17	19.22	0.407	0.453	0.519	54
18	9	20	14.02	0.449	0.496	0.559	47
19	12	10	45.19	0.231	0.3	0.442	54
Minimum-All Tests			2.77	0.136	0.152	0.162	29
Maximum-All Tests		45.19	0.449		0.496	0.559	59

*Average of 4 repeats

TABLE 4. WAVE STUDY - HARBOR CHOP WAVES (JO 61-3)

Test no.	Stroke in.	CPM	H(1/3) m	H(1/10) m	H(max.) m
32	1.5	30	0.222	0.284	0.352
34	3	20	0.272	0.326	0.435
35	3	25	0.33	0.417	0.497
36	4.5	20	0.451	0.557	0.634
37	4.5	35	0.426	0.581	0.725
38*	6	20	0.492	0.581	0.662
39	6	25	0.538	0.661	0.875
40	7.5	15	0.463	0.549	0.682
41	7.5	19	0.506	0.569	0.629
42	9	16	0.292	0.351	0.408
43	10.5	16	0.502	-0.55	0.595

*Average of 4 repeat tests.

Intermixing of video and film records can be accomplished by multiplexing video tape to 16-mm film stock. After selecting the desired video footage, the photographer directs a subcontractor laboratory in transfer operations. The output film is selected by the photographer to fulfill a wide range of requirements.

Still (35 mm) and movie (16 mm) photographic documentation is available for reports, public release, and qualitative and quantitative analysis. Modes of operation include high speed, time lapse, aerial, semi-aerial, underwater, quasi-underwater (through windows), fixed plane, micro, macro, large format, and remote triggering. All processing is done by outside contractors with fast and custom processing available. Still and movie cameras can be positioned underwater or topside.

Besides wishing to view the testing and performance of a system, the tank user may wish to have a professional film edited, scripted, and presented for public or in-house viewing. A professional film producer is available for 16 mm color-sound movie production.

Report Preparation

OHMSETT personnel have produced many reports published by the EPA, United States Coast Guard (USCG), and Department of Energy (DOE). The facility's personnel have developed appropriate methods, procedures and some of the terminology involved in testing and analyzing the unique devices which arrive for evaluation. A formal report written to EPA standards and processed through rough draft to final report includes typing and a camera ready copy of the final report. Illustrations, tables, and photographs are included to emphasize, demonstrate, and summarize important aspects of the test project. All reports follow guidelines established by the Handbook for Preparing Office of Research and Development Reports (EPA-600/9-78-032), unless otherwise requested by the tank user. Whether the tank user wishes to delegate the report preparation or take it upon himself, the OHMSETT staff is available for consultation on any matter related to testing.

Normally, the user is provided with tabulated data for each test as well as graphical presentations of data on a daily basis. Also, all raw data sheets are available upon request, but no write-up of conclusions or discussion of results is provided unless specifically requested and funded.

Shop

A shop and equipment preparation area is available for assembly or modification of test devices. Equipment available includes carbon steel, stainless steel, and aluminum welders; oxy-acetylene welder; drill press; 12-mm lathe; 45 metric ton press; and an assortment of wood and metal working equipment.

Two semi-tractors are available along with several flatbed trailers and nine 19 m^3 tank trailers. Additional transportation services are available through the U.S. Navy on whose property OHMSETT is located. Two 2.7 metric ton forklifts and two 18 metric ton cranes are OHMSETT-owned. Cranes up to 63 metric ton are available from the U.S. Navy and lifts to 181 metric ton are possible using subcontractor crane services.

PROCEDURE FOR OHMSETT USE

The tank user's initial contact with OHMSETT is through the U.S. Environmental Protection Agency's office in Edison, New Jersey. The EPA Project Officer will meet with the potential tank user to discuss the user's requirements. General aspects such as project scope, facility capabilities and limitations, costs and dates will be discussed at that time. When the tank user is a governmental organization, an interagency agreement (IAG) for the use of the OHMSETT facilities will be drawn up between the user and the U.S. EPA. A job order will then be written and a test date will be placed on the OHMSETT schedule by the U.S. EPA Project Officer and given to Mason & Hanger, EPA's OHMSETT contractor. Private organizations contract directly with Mason & Hanger-Silas Mason Co., Inc. with consent of the EPA.

Detailed mechanical and testing aspects, specific to the project, will be worked out at later meetings at OHMSETT by the EPA Project Officer, Mason & Hanger Test Engineers, and the tank user. EPA and Mason & Hanger will endeavor to work in a coordinated effort with the user in order to perform the desired testing in the most professional, economical, and expedient way possible.

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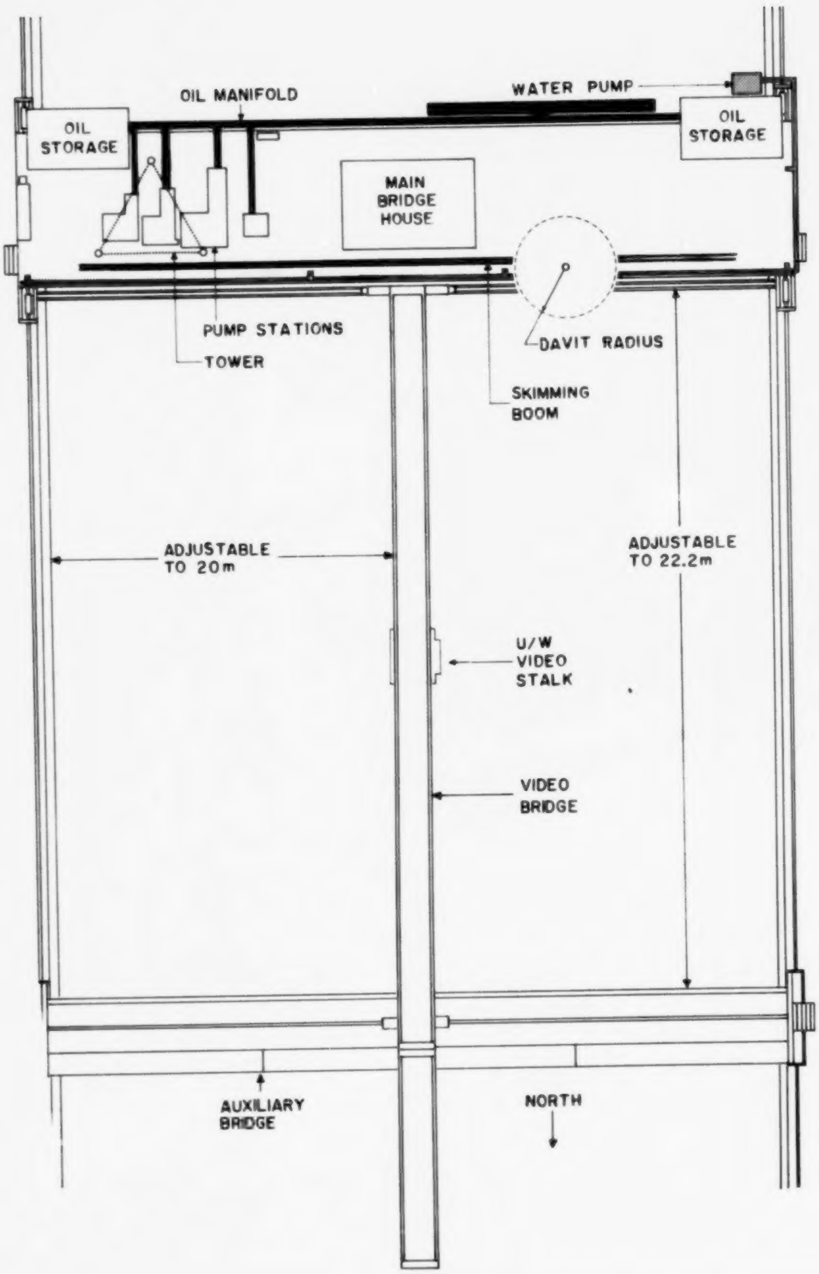
OIL MANIFOLD
WATER PUMP
OIL STORAGE
OIL STORAGE
MAIN BRIDGE HOUSE
PUMP STATIONS
TOWER
DAVIT RADIUS
SKIMMING BOOM
ADJUSTABLE TO 20m
ADJUSTABLE TO 22.2m
U/W VIDEO STALK
VIDEO BRIDGE
AUXILIARY BRIDGE
NORTH

Figure 1. Top View of all OHMSETT Bridge Systems. Main Bridge is shown at top. Auxiliary Bridge, at bottom of drawing, is adjustable and may also be removed from the cable drive. The Video Bridge connects the Main and Auxiliary Bridges and carries a mounting strut for the underwater video camera. Video Bridge is also removable.

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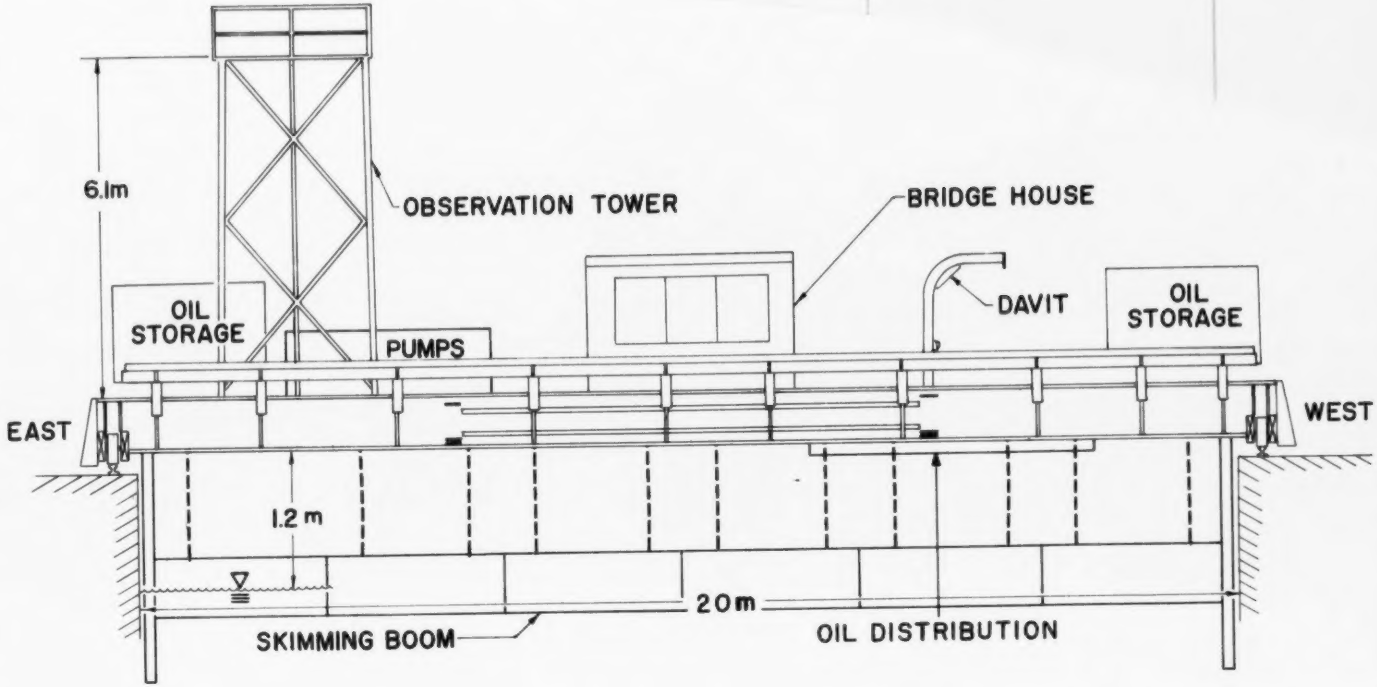
6.1m
OBSERVATION TOWER
BRIDGE HOUSE
DAVIT
OIL STORAGE
PUMPS
OIL STORAGE
EAST
WEST
1.2 m
20 m
SKIMMING BOOM
OIL DISTRIBUTION

Figure 2. Side View of the Main Bridge. Test fluids are stored in two tanks, one on each end of the bridge, and distributed onto the water surface through a manifold system using four onboard pumps. Three manifolds are available for distribution using several widths and flowrates. A fire hose system is available for use in controlling the oil slick and is used for cleanup with the aid of a skimming boom. The photo tower is used for overhead observation and photography of tests. Bridge house contains facilities for electronic instrumentation, photo/video cables, data cables, and wave measuring instrumentation.

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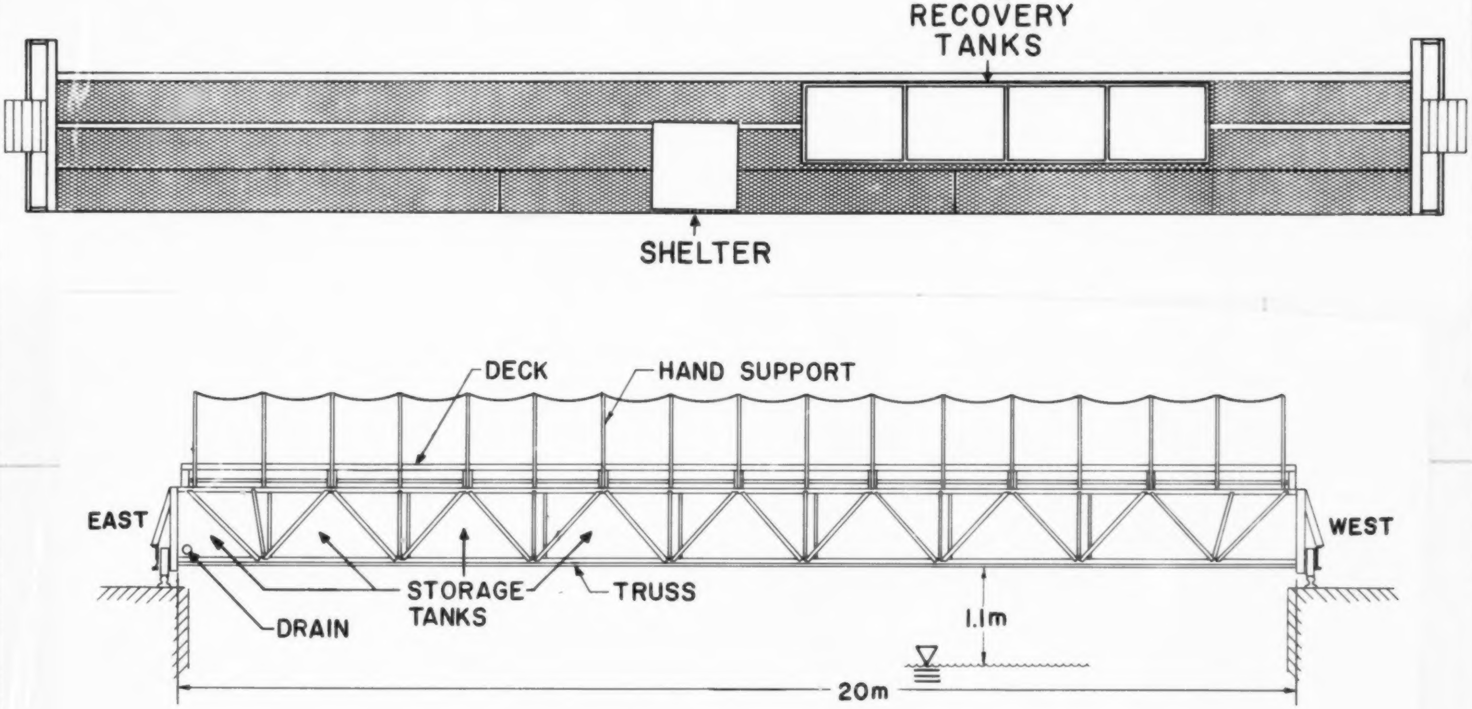
OIL
RECOVERY
TANKS
SHELTER
DECK
HAND SUPPORT
EAST
WEST
STORAGE
TANKS
TRUSS
DRAIN
1.1m
20m

Figure 3. Auxiliary Bridge. This bridge is normally used to support skimmer-recovered fluid storage tanks and for towing test devices back to the North tank end following a test. Below-deck integral storage tanks hold up to 9.5 m^3 of recovered fluid and portable tanks to hold another 7.6 m^3 can be placed on top of the deck.

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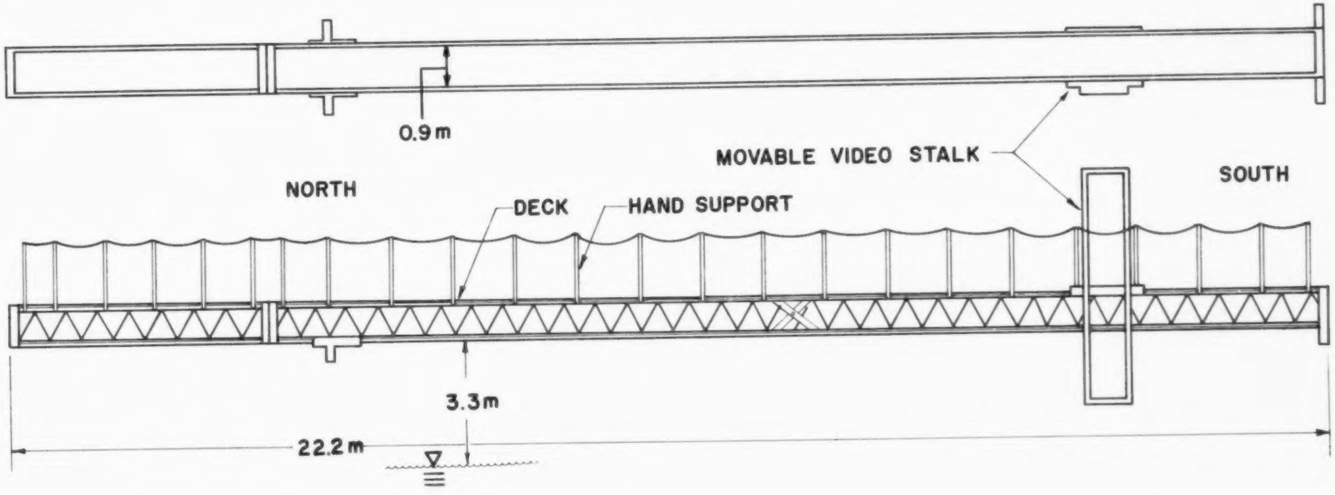
0.9m
MOVABLE VIDEO STALK
NORTH
SOUTH
DECK
HAND SUPPORT
3.3m
22.2m

Figure 4. Video Bridge. Personnel are not allowed to ride on this bridge when test speeds exceed two knots and when over 19.2 m of video bridge is used to span between the main and auxiliary bridges.

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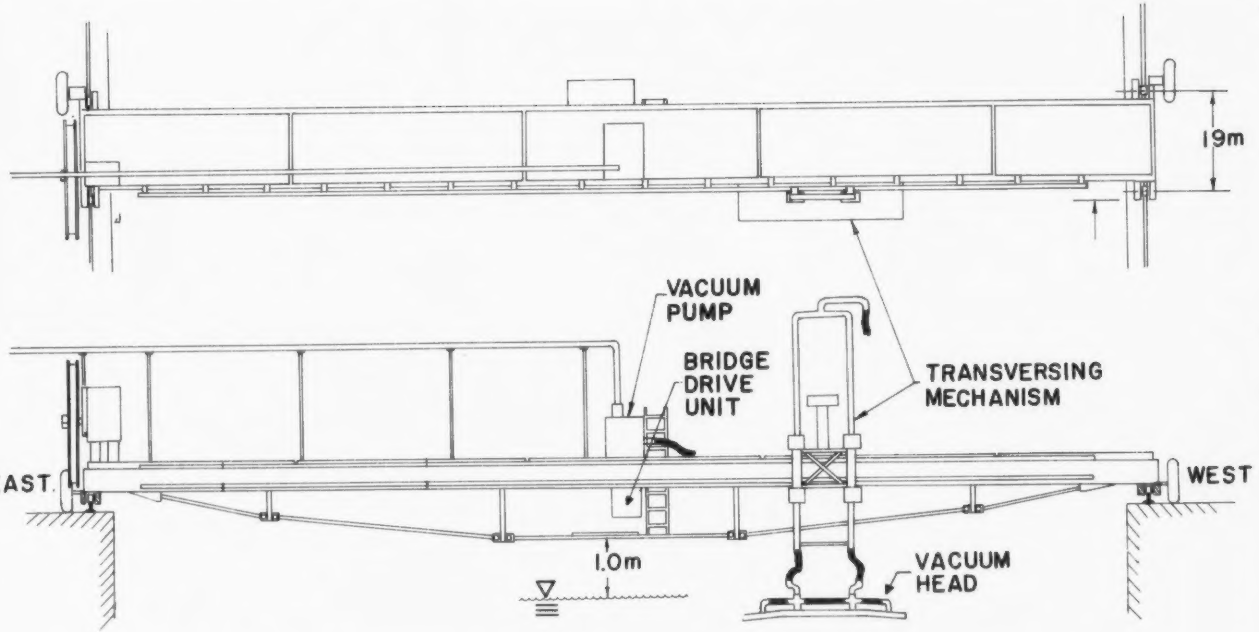
19m
VACUUM PUMP
BRIDGE DRIVE UNIT
TRANSVERSING MECHANISM
EAST
WEST
1.0m
VACUUM HEAD

Figure 5. Vacuum Bridge. This bridge is normally used to clean the tank bottom but it may also be attached to the cable drive for use in testing.

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SECTION 2

TEST DESIGN

BOOM PERFORMANCE TESTS

A boom may be tested in several different configurations, such as catenary or diversionary arrangements. The length of the boom to be tested generally should be adjusted so that the boom will assume the same shape as it would in the intended application. The effects caused by the tank side walls and bottom must be considered when planning a test. In some cases, it is inadvisable to rig a boom the full width of the tank, so that side wall effects are reduced.

Boom performance is generally based on the quantity of fluid contained or controlled by the boom. Failure modes are easily detected with the photo/video qualitative measurements. The more common failure modes are:

1. fluid entrainment in the water column due to interfacial shear, gravity waves, capillary waves, or eddy currents,

2. fluid loss over the top of the boom due to heaving or splashing,

3. fluid leakage at boom section joints,

4. boom stability failure due to planing, submarining, oscillating, or bridging, and

5. fluid draining due to excessive thickening ahead of the boom.

In a comprehensive test series, these possible failure modes will be examined over a range of tow speeds, wave conditions, and oil encounter rates. For oil containment tests, it is necessary to preload the boom with a large pool of oil.

In addition to the photo/video documentation, tow force is usually measured.

SKIMMER PERFORMANCE TESTS

The detailed test procedures for oil recovery skimmers may vary somewhat from skimmer to skimmer because of differences in the operating principles and actual mechanisms. Certain considerations apply to nearly all tests, however.

Skimmer performance is evaluated at OHMSETT both quantitatively and qualitatively. Quantitative measures of performance in an oil recovery test are oil recovery rate (ORR), recovery efficiency (RE), and throughput efficiency (TE). ORR is the volume of oil recovered by the skimmer per unit time. RE is the ratio of the volume of oil recovered to the volume of fluid (oil and water) collected. TE is the ratio of the volume of oil recovered to the volume of oil encountered by the skimmer during the same time interval.

The user generally wishes to know what would be the performance of the skimmer over the course of many hours of steady operation. To get the best indication of this, data accumulated during the brief starting and stopping periods are usually ignored, and the above three performance parameters are calculated from data taken after the skimmer has reached steady-state conditions. The total volumes recovered may be compared with discrete samples taken at intervals during the test run to confirm the steady-state conditions.

Fluid encounter rates (i.e., slick width and thickness) are selected based on two criteria. One is the expected maximum recovery rate of the device; an encounter rate equal to or greater than this will be used in at least one test. Another criterion is the thickness of typical uncontained slicks; slicks 0.5 to 5 mm thick are usually selected on this basis.

Wave conditions may be selected based on a variety of criteria. Usually at least one regular wave equal in length to the length of the device and one twice the length of the device are selected.

The details of a skimmer's rigging and the detailed test procedure require careful planning. Consultation with an OHMSETT test engineer is essential.

OTHER DEVICES

Because of the great versatility of the shop and other support facilities, the tank may be used for testing a wide variety of devices besides booms and skimmers. In the past, this has included testing sorbent materials and their dispensing systems, slick detectors, oil gelling agents and dispensing systems, and dispersant application systems. In addition, experiments on the behavior of oil have been conducted, and the possibility of testing with ice in the tank is being investigated.

PERFORMANCE DATA COLLECTION

Collected fluids are measured on a total volume basis over a specific time period. For instance, a collection tank may be filled with 1.1 m^3 of the oil/water fluid collected by the skimmer during a 240 second test period (a 17 m^3/hr total fluids recovery rate). Actual oil recovered is calculated from a sample taken from the tank, analyzed in the OHMSETT chemistry lab for percent oil and multiplied by the volume of fluid collected.

Most skimming systems tested have various adjustable design features such as gill doors, pump speeds, freeboards and weir height. These adjustments are recorded at OHMSETT because they often cause changes in performance (TE, RE, ORR). A composite list of measured variables to be considered may include as many as six categories of items.

TABLE 5. TYPICAL TEST VARIABLES

Dependent	Independent
Throughput efficiency	Tow speed
Oil recovery efficiency	Oil slick dimensions
Oil recovery rate	Sea conditions
	Oil properties
	Skimmer settings
	Weather conditions

Photography with 35-mm still and 16-mm motion pictures is complemented by instant-replay video tape capability in both color and black/white. Underwater, topside and coverage through the tank wall window may all be obtained in a given test series. Permanent records are thus obtained of oil-loss mechanisms, making possible qualitative evaluations of performance and test credibility. The test fluids are usually treated with dyes to enhance visual contrast. Grids and other visual aids are sometimes painted on devices to further enhance the visually recorded data. Observers' comments during each test run are recorded on tape cassettes for most test programs.

IMPLEMENTATION OF TEST PLANS

The primary operational objective is to accomplish the greatest number of good tests per unit time in a safe manner. Therefore, testing takes precedence over all other activity and personnel make every effort to optimize tank use. All testing projects are managed by a Test Engineer and are conducted under his supervision by a Test Director according to a Test Plan (see Appendix A). The Test Director ensures orderly execution of tests, utilizes the tank and associated systems to the best possible advantage, and ensures orderly and complete collection of data. The Test Engineer coordinates, on a continuing basis with the user and ensures his needs are being met.

Prior to the execution of tests, a written Test Plan must be developed. This plan may be revised as the test progresses in order to meet overall study objectives. Revisions will be developed jointly by the user and the Test Engineer. The Test Engineer and Test Director will aid the tank user in composing his Test Plan.

Mason & Hanger-Silas Mason Co., Inc.'s purpose at OHMSETT is to operate and maintain all systems and equipment for the U.S. Environmental Protection Agency. Use of the facility by all users is under the control of the EPA Project Officer.

As standardized test plans are developed by the Environmental Protection Agency, the user will also have the alternative of choosing to use them, and thus benefit from established test execution accuracies and statistical precision. Standardized test plans do not require additional guidance and overview from the Test Engineer.

SECTION 3

OHMSETT OPERATIONAL JOB ORDERS

JOB ORDER NO. 1 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 2 June 1974 to Present

Customer Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Description of Program

Support of U.S. EPA projects as directed.

JOB ORDER NO. 2 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 2 June 1974 to Present

Customer Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Description of Program

OHMSETT General Operations Budget.

JOB ORDER NO. 3 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 2 June 1974 to Present

Customer Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Description of Program

OHMSETT maintenance budget. Merged with JO-2 in January 1979.

SECTION 4

TESTS PERFORMED IN 1974

JOB ORDER NO. 4 - U.S. COAST GUARD

Dates 19 August - 26 September 1974

Customer
Office of Research and Development
U.S. Coast Guard
G-DMT-4/TP54
Washington, DC 20593 202-426-1023

Devices
Lockheed High Seas Oil Recovery System (HSORS)
Lockheed Missiles & Space Co., Inc.
P.O. Box 504, Bldg. 570
Sunnyvale, CA 94086 408-988-0906

Oil Recovery System 1000 (ORS-1000)
Ocean Systems, Inc.
14400 Isaac Newton Industrial Square
North Reston, VA 22010 703-471-1310

Report Chang, W.J. Tests of Coast Guard Developed High Seas Oil Recovery System at EPA OHMSETT. April 1975. CG-D-101-75, NTIS #ADIA-014 495 (Ref. 15).

Description of Program

Objectives of this program were to obtain quantitative and qualitative measures of performance for the Lockheed High Seas Oil Recovery System (HSORS) and the Ocean Systems, Inc. Oil Recovery System 1000 (ORS 1000). In addition, a standard test procedure was developed for the testing of advancing oil skimmers.

The tests were controlled and instrumented to yield data on the oil recovery rate, oil recovery efficiency, and throughput efficiency over a wide range of conditions.

Conclusions

The following conclusions are supported by the results of this testing:

Lockheed HSORS

1. The HSORS is capable of operation in 2 foot waves of either 3 or 6 second period; the waves have a small effect on performance.
2. The HSORS achieved peak oil recovery rate of 112 m^3/hr.
3. The HSORS achieved a peak recovery efficiency of 99%. Only 9 of the recovery efficiencies were less than 90%.
4. The HSORS achieved a peak throughput efficiency of 91%. Most of the other throughput efficiencies were considerably lower.
5. The HSORS should be used within the bucket of a containment barrier since loss rates without a barrier are very high.
6. The HSORS is extremely sensitive to viscosity. Recovery rates for #2 Fuel Oil were always less than 11.4 m^3/hr.
7. The HSORS is easily deployed and retrieved.
8. The HSORS is capable of efficient operation in 0-2 knot currents.

Ocean Systems Inc. ORS 1000

1. The ORS 1000 is capable of operation in 2 foot waves of either 3 or 6 second period. However, the waves severely affect the performance of the device particularly the waves of 6 second period.
2. The ORS 1000 achieved a peak oil recovery rate of 158 m^3/hr.
3. The ORS achieved a peak recovery efficiency of 95%. Only 14 recovery efficiencies were greater than 50%.
4. The ORS 1000 achieved a peak throughput efficiency of 82%. Most of the other throughput efficiencies were considerably lower.
5. The ORS 1000 should be used integrally with a containment barrier to allow oil to build up in front of it and thicken in the basin.
6. The ORS 1000's recovery is independent of viscosity over the range 0-600 cSt.
7. The ORS 1000 is capable of efficient operation in 0.75-2 knot currents.
8. The ORS 1000 is difficult to assemble, deploy, and disassemble.

Test Apparatus

1. The ADAPTS pump oil distribution (using one pump) system is capable of distributing #2 Fuel Oil at rates in excess of 290 m^3/hr, a 250 cSt oil at rates in excess of 216 m^3/hr and a 500 cSt oil at rates in excess of 170 m^3/hr.

2. The ADAPTS pump oil distribution system is not suitable for use below about 45.4 m^3/hr since flow variations are great below this point. Considering the job for which these pumps are designed, they performed remarkably well.

3. Use of a synchronized bridge tractor trailer combination for oil distribution and recovery systems is feasible provided a low speed tractor is available.

4. The lightweight boom used on the tank ends and the polyethylene sheeting of the tank walls are unnecessary for future tests.

Instrumentation and Data Recording, Reduction, and Analysis

1. The venturi flowmeters used on the distribution and recovery manifolds are usable but calibration of them with the fluids to be encountered is required. Their output is affected by the specific gravity of the fluid flowing through them and so the error introduced in the recovery flowmeter by assuming the specific gravity to be the average specific gravity for the recovered fluid (approximately 10%) must be accepted if we are to use it again.

2. A number of strain gauges with different ranges are required if we are to measure towing tensions accurately.

3. The capacitance probe technique is suitable for use in a test tank situation.

4. The electromagnetic current meter is usable to measure tow speed but a more straightforward technique is desirable.

5. The oil thickness sonar is usable but the system should be refined to lower its threshold and to make its output simple and less subject to interpretation.

6. The Rustrak recorders are too slow both in chart speed and response. Other chart recorders should be acquired.

7. Provision for an event marker must be made on the recording system.

8. On site data reduction and plotting is required to derive maximum utility from the system.

TABLE 6. LOCKHEED TEST MATRIX (JO 4)

Test no.	Oil viscosity cSt @21°C	Tow speed (kts)	Wave condition H (m)	Wave condition P (sec)	Distribution rate m^3/hr	Oil thickness (mm)
1*	1000	2.0	0	0	140	6
1r*	1000	2.0	0	0	7	0.2
1r^2	1000	2.0	0	0	66	3
2	1000	2.0	0.6	3	70	3
2r	1000	2.0	0.6	3	102	5
2r^2	1000	2.0	0.6	3	87	4
3	1000	2.0	0.5	6	168	8
3r	1000	2.0	0.5	6	76	3
4*	1000	0.75	0	0	126	15
4r	1000	0.75	0	0	41	5
5	1000	0.75	0.6	3	136	16
5r	1000	0.75	0.6	3	92	11
6	1000	0.75	0.5	6	124	15
6r	1000	0.75	0.5	6	59	7
6r^2	1000	0.75	0.5	6	74	9
7	1000	0.75	0	0	153	18
7r	1000	0.75	0	0	149	18
8	1000	0.75	0.6	3	120	14
8r	1000	0.75	0.6	3	164	20
9	1000	0.75	0.5	6	153	18
10	500	2.0	0	0	94	4
11	500	2.0	0.6	3	72	3
12	500	0.75	0	0	21	2
13	500	0.75	0.6	3	18	2
14	500	0.75	0.5	6	67	8
15	500	1.0	0	0	191	18
16	500	1.0	0.6	3	91	8
17	500	1.0	0.5	6	146	13
18	500	1.5	0	0	216	13
19	500	0.75	0	0	194	23
20	500	0.75	0.6	3	71	8
21	500	0.75	0.5	6	57	7
22	5	1.0	0	0	35	3
23	5	1.0	0.6	3	154	14
24	5	1.0	0.5	6	4	0.5
25	5	0.75	0	0	117	14
26	5	0.75	0.6	3	153	18
27	5	0.75	0.5	6	154	18
28	5	1.0	0	0	32	0.2
29	5	1.0	0.6	3	226	19
30*	5	1.0	0.5	6	290	26

(Continued)

TABLE 6. (Continued)

Test no.	Oil viscosity cSt @21°C	Tow speed (kts)	Wave condition H (m)	Wave condition P (sec)	Distribution rate m^3/hr	Oil thickness (mm)
49	500	1.5	0	0	57	3
50	500	1.5	0.6	3	11	0.8
51	500	1.5	0.5	6	42	2
57	1000	1.0	0	0	141	13
58	1000	1.0	0.6	3	138	12
59	1000	1.0	0.5	6	135	12

NOTE: Asterisks indicate values based on tank soundings and stopwatch times instead of flowmeter readings. The designations (r) and (r^2) indicate first and second repetitions, respectively, of a test.

TABLE 7. LOCKHEED TEST RESULTS (JO 4)

Test no.	Oil recovery rates avg. m^3/hr	Oil recovery rates peak m^3/hr	Recovery efficiencies avg. %	Recovery efficiencies peak %	Throughput efficiency %
1*	36	44	81	98	35
1r*	38	127	93	93	(326)
$1r^2$	16	70	40.7	60.7	21
2*	8	23	24	72	09
2r*	32	33	85	87	38
$2r^2$	31	58	37.9	64.7	37
3*	12	12	64	65	07
3r	24	56	57.5	63.6	31
4*	25	26	77	82	17
4r	19	70	73.1	88.7	54
5	41	47	85	98	54
5r	19	91	56.5	95.0	44
6*	33	35	91	98	25
6r*	61	63	75.3	97.3	(155) 54*
$6r^2$*	17	17	91	91	91
7*	40	47	73	86	39
7r	53	81	83.6	90.7	47
8*	43	44	90	92	51

(Continued)

TABLE 7. (Continued)

Test no.	Oil recovery rates avg. m^3/hr	Oil recovery rates peak m^3/hr	Recovery efficiencies avg. %	Recovery efficiencies peak %	Throughput efficiency %
8r	58	91	88.8	92.0	41
9	52	88	89.6	93.3	58
10	3	26	85.5	94.2	03
11	31	77	96.8	98.3	42
12*	72	89	89.6	96.6	(457) 42*
13*	29	63	86.1	93.3	(214) 52*
14	25	56	95.4	98.7	67
15	56	93	93.7	96.4	44
16*	20	20	92	92	23*
17	39	79	86.2	92.3	31
18	71	99	92.1	92.6	38
19	46	67	96.4	98.3	44
20*	37	65	94.1	96.5	(108) 33*
21	53	67	91.0	97.2	(129) 37*
22	21	55	93.2	95.3	(116) 05*
23*	0	0	92.2	97.6	0
24*	10	102	96.0	96.8	36*
25*	11	12	93.0	95.6	43*
26*	7	8	97.1	98	22*
27*	7	11	95.3	97.3	16*
28	3	86	93.5	96.1	26
29*	7	8	95	97	10*
30*	7	9	95.3	96.8	07*
49	53	67	91.0	97.2	(137) 204*
50*	7	7	97	99	116*
51	42	56	97.4	97.9	(133) 73*
57	59	128	91.3	93.6	70
58	46	167	74.3	90.0	56
59	67	161	93.5	94.1	66

NOTE: Asterisks indicate values based on tank soundings and stopwatch times instead of flowmeter readings.

Throughput efficiencies in parenthesis are greater than 100%, which are impossible and reflect errors in the measurement techniques.

TABLE 8. OCEAN SYSTEMS INC. TEST MATRIX (JO 4)

Oil Test no.	Tow viscosity cSt @ 21°C	speed (kts)	Wave condition		Distribution rate m³/hr	Oil thickness (mm)
			H (m)	P (secs)		
4*	5	1.4	0	0	72	.17
4r	5	1.5	0	0	86	.20
5	5	1.5	.6	3	81	.19
6	5	1.5	.5	6	32	.08
7	5	2.0	0	0	84	.15
7r*	5	2.0	0	0	100	.18
8*	5	2.0	.6	3	64	.11
9*	5	0.4	0	0	91	.80
10*	5	0.3	0	0	140	1.64
11*	5	0.7	0	0	79	.40
12	5	0.5	0	0	53	.37
13*	5	0.5	0	0	45	.32
13r	5	0.75	0	0	77	.36
14	5	1.0	0	0	67	.24
14r	5	1.0	0	0	128	.45
15*	5	1.0	.6	3	220	.77
16	5	1.0	.5	6	88	.31
16r	5	1.0	.5	6	136	.48
17	5	.75	0	0	142	.66
18*	5	.75	.6	3	102	.48
19*	5	.75	.5	6	125	.59
23	500	1.5	0	0	75	.18
24	500	1.5	.6	3	78	.18
25	500	1.5	.5	6	84	.20
26	500	2.0	0	0	92	.22
27*	500	2.0	.6	3	83	.20
28*	500	.75	0	0	105	.49
65*	5	.75	0	0	92	.43
29	500	.75	.6	3	100	.47
30	500	.75	.5	6	110	.52
34	5	.75	0	0	75	.35
36	5	.75	.5	6	88	.41
40	5	2.0	0	0	286	.50
40r	5	2.0	0	0	289	.51
41	5	2.0	.6	3	223	.39
44	5	1.0	0	0	279	.98
46	5	1.0	.5	6	288	1.02
47	5	1.5	0	0	183	.66
50	500	1.0	0	0	37	.13
51	500	1.0	.6	3	158	.56
52	500	1.0	.5	6	134	.47

(Continued)

TABLE 8. (Continued)

Oil Test no.	Tow viscosity cSt @ 21°C	speed (kts)	Wave condition H (m)	P (secs)	Distribution rate m³/hr	Oil thickness (mm)
53	500	1.5	0	0	181	.42
54	500	1.5	.6	3	211	.49
55	500	1.5	.5	6	207	.49
56	500	.75	0	0	143	.67
57	500	.75	.6	3	68	.32
58	500	.75	.5	6	138	.65
59	5	.75	0	0	45	.21
60	5	1.0	0	0	149	.52
61	5	1.0	.5	6	149	.52
62	500	1.0	0	0	110	.39
63	500	1.5	0	0	121	.28
64	500	2.0	0	0	195	.34

NOTE: Asterisks indicate values based on tank soundings and stopwatch times instead of flowmeter readings.

TABLE 9. OCEAN SYSTEMS INC. TEST RESULTS (JO 4)

Test no.	Oil Recovery Rates Avg. m³/hr	Oil Recovery Rates Peak m³/hr	Recovery Efficiencies Avg. %	Recovery Efficiencies Peak %	Throughput Efficiency %
4*	12	58	13	56	22
4r	38	127	52	93	31
5	17	45	15	27	23
6	15	46	11	24	49
7	0	0	0	0	0
7r	0	0	0	0	0
8	0	0	0	0	0
9*	4	10	03	09	04
10	0	0	0	0	0
11*	6	24	14	22	59
12	0	0	0	0	0
13*	2	11	2	13	15
13r	7	22	7	15	24
14*	66	140	5	15	73

(Continued)

TABLE 9. (Continued)

Test no.	Oil Recovery Rates Avg. m^3/hr	Oil Recovery Rates Peak m^3/hr	Recovery Efficiencies Avg. %	Recovery Efficiencies Peak %	Throughput Efficiency %
14r	57	164	27	67	(112)118
15	24	60	16	39	26
16*	2	9	02	10	05
16r	41	77	21	31	82
17	7	29	6	13	08
18*	3	23	3	21	12
19	0	0	0	0	0
23	7	27	4	15	11
24	0	0	0	0	0
25	5	33	6	21	10
26	20	63	13	39	27
27*	13	41	12	25	27
28	28	90	17	51	(107)25
29	8	30	6	15	22
30	0	0	0	0	0
34	9	72	13	48	40
36	0	0	0	0	0
40*	56	76	19	25	22
40r	72	113	37	50	29
41	77	151	43	74	37
44	71	190	45	76	51
46	68	152	33	60	30
47	50	78	27	33	32
50*	86	226	39	95	(307)80
51	55	71	22	28	70
52	43	65	19	27	74
53	18	45	13	17	12
54	117	158	55	62	65
55	55	83	28	38	35
56	40	161	17	58	74
57*	6	37	2	50	16
58	8	30	9	27	20
59*	3	7	9	20	27
60	30	67	26	39	20
61	29	55	14	22	37
62	90	150	38	63	41
63	104	162	49	69	45
64	74	118	33	46	19
65*	7	22	10	26	25

JOB ORDER NO. 5 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	4 October - 2 November 1974	
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817	201-321-6600
Device	Trailer-Mounted Carbon Adsorption Trailer	

Description of Program

OHMSETT personnel responded to a polychlorinated biphenyl (PCB) spill in Seattle, WA. A trailer-mounted carbon adsorption system developed for EPA was used to remove PCB vacuumed from the harbor bottom.

SECTION 5

TESTS PERFORMED IN 1975

JOB ORDER NO. 6 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 2 February - 6 June 1975; 15 August 1975

Customer
Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Devices
Harbour Boom
Clean Water, Inc.
Courthouse Square
P.O. Box 1002
Toms River, NJ 08753 201-341-3600

T-T Boom
Coastal Services, Inc.
22 River Street
Braintree, MA 02184 617-848-4820

O.K. Corral Boom
Acme Products Co.
P.O. Box 51388
2666 N. Darlington Avenue
Tulsa, OK 74151 918-836-7184

Permafloat Sea Boom, 18 PFX
B.F. Goodrich Sea Products
430 S. Main Street
Cohasset, MA 02025 617-383-6000

Mark VI Boom
Slickbar, Inc.
P.O. Box 139
250 Pequot Avenue
Southport, CT 06490 203-255-2601

Sea Curtain Boom
Kepner Plastics Fabricators, Inc.
3131 Lomita Blvd.
Torrance, CA 90505 213-325-3162

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Petroleum Association for Conservation of the Canadian Environment (PACE) Boom
Box 400 Terminal A
Toronto, Ontario, M5W 1E1 416-597-7040

Expandi-Boom
Whittaker Corp.
5845 River Road
New Orleans, LA 70183 504-733-7050

5159 Baltimore Drive.
La Mesa, CA 92041 714-469-0171

2600 S. Gessner, Suite 311
Houston, TX 77063 713-784-0650

Rigid Manta Ray Skimmer, 2.5 mm
Flexible Manta Ray Skimmer, 2.5 mm
Flexible Manta Ray Skimmer, 1.3 mm
Aluminum Skimmer
Slickbar, Inc.
P.O. Box 139
250 Pequot Avenue
Southport, CT 06490 203-255-2601

Floating Saucer SK-39T Skimmer
Acme Products Co.
P.O. Box 51388
2666 N. Darlington AVenue
Tulsa, OK 74151 918-836-7184

Komara Miniskimmer
British Petroleum Co., Ltd.
BP Research Center
Chertsey Road
Sunbury-on-Thames
Middlesex, England TW16 7LN 85533 EXTN

Slurp Skimmer
Coastal Services Inc.
22 River Street
Braintree, MA 02184 617-848-4820

Kaiser OELA-III Swiss Oil Skimmer
Industrial and Municipal Engineering (IME)
P.O. Box N
U.S. Route 34 East
Galva, IL 61434 309-932-2036

Report McCracken, W.E. Performance Testing of Selected Inland Oil Spill Control Equipment. EPA-600/2-77-150, U.S. Environmental Protection Agency, 1977 (Ref. 35).

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Description of Program

Standardized performance tests were conducted with various off-the-shelf inland oil spill control and cleanup devices. Eight boom systems were tested in a catenary configuration for oil containment capabilities and in the diversionary configuration for fast current oil diversion. Test parameters included tow speed, wave conditions, and oil type (No. 2 fuel oil and a lubricating stock). Eight stationary skimmers were evaluated over the same range of wave and oil conditions. Operating techniques were recommended, especially for viscous oil. A 16 mm color, sound movie, entitled, "The OHMSETT Report - A Test Program," was produced and is available from Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268. A technical report (EPA-600/2-77-150) is available from NTIS. (Ref. 35)

Conclusions

The following conclusions are based on standardized testing of various off-the-shelf inland oil spill control and clean-up skimmers and barriers. The testing was undertaken to relate various salient design features to performance in various waves and currents representative of those found in inland waterways. Direct comparison of booms and skimmers was avoided. Each boom and skimmer system was recognized as having its place of application in the wide range of environmental conditions that exist on the inland waterways. The tests conducted at OHMSETT defined the range of waves and currents under which each type of system would perform. Only performance tests were conducted.

For boom systems, the relationship between net buoyancy, skirt draft, towing arrangement, and maximum tow speeds (currents) relative to waves are:

1. Catenary Boom Stability above 1.6 knot current and 0.61 m wave (.067 steepness ratio, H/L)

   a. Net Buoyancy 44.6 kg/m
   b. Skirt Draft 0.3 m
   c. Towing Arrangement...tension concentrated near bottom

2. Catenary Boom Containment at 1.0 kt current and 0.61 m wave (.067 H/L)

   a. Net Buoyancy 10.4 to 29.8 kg/m
   b. Skirt Draft 0.15 to 0.30 m
   c. Towing Arrangement...tension concentrated near bottom

3. Diversionary Boom Stability above 1.6 kt current and 0.61 m wave (.067 H/L)

   a. Net Buoyancy 37.2 kg/m
   b. Skirt Draft 0.46 m
   c. Towing Arrangement...tension concentrated near bottom

4. Diversionary Boom Diversion above 1.1 kt current and 0.61 m wave (.067 H/L)

   a. Net Buoyancy 37.2 kg/m
   b. Skirt Draft 0.46 m
   c. Towing Arrangement...tension concentrated near bottom

All boom tests, excepting one, were conducted with a high viscosity lubrication grade oil. To illustrate the effect of a low viscosity oil on boom performance, one boom system was tested with both the lubrication oil and No. 2 fuel oil. The results indicated a slight decrease in the critical tow speed (no oil loss speed) of 0.15 kt.

Considering the eight boom systems as representing the current technology for spill control systems on inland waterways, the optimum performance for all of the booms at the various conditions was:

1. Catenary Configuration (Stability Performance): Maximum Stable Tow Speed ranged from 0.5 kt at a wave steepness ratio of 0.111 to 2.5 kt at calm water conditions.

2. Catenary Configuration (Performance with Oil): Maximum "No Oil Loss" Tow Speed ranged from 0.5 kt at a wave steepness ratio of 0.111 to 0.9 kt at calm water conditions.

3. Diversionary Configuration (Stability Performance): Maximum Stable Tow Speed ranged from 0.5 kt at a wave steepness ratio of 0.111 to 2.0 kt at calm water conditions.

4. Diversionary Configuration (Performance with Oil): Maximum "No Oil Loss" Tow Speed ranged from 0.5 kt at a wave steepness ratio of 0.111 to 1.6 kt at calm water conditions.

The diversionary capability of each boom system to divert oil from the fast current regions on an inland waterway to the slow current regions where oil collection (i.e. skimmers) is initiated was determined. For currents greater than 1 kt, with the boom in the catenary configuration, the tank tests indicated that the oil could not be contained. In that most inland waterways have surface currents in excess of 1 kt, diversionary boom techniques are most successful. From vectorial analysis of the forces exerted on a boom by the current, the theoretical benefit of angling a boom relative to the current can be easily calculated. However, deploying a flexible boom to maintain a constant angle along its entire length is impossible. Thus, parachute mooring lines and other techniques are used to maintain the current directly perpendicularly against the boom below the 1 kt limit.

In that booms and skimmers must operate in the same environmental conditions, the skimmers were tested with the same wave conditions as the booms. Two different oils were used to test skimmer performance and their dependence on oil viscosity. The oil slick thickness was controlled at 2.54 cm which represents actual inland-use situations where the oil slick is thickened either by containment in a boom moving against the current, or by diversion along a boom angled against the current.

TABLE 10. OPTIMUM BOOM STABILITY PERFORMANCE MAXIMUM STABLE TOW SPEED (JO 6)

H/L	Wave characteristics H x L x P m x m x secs	Containment critical tow speed+ kts	Diversionary critical tow speed+ kts
0.111	0.3 x 2.7 x 1.5	0.5	0.5
0.067	0.6 x 9.1 x 3.0	1.94	2.04
0.022	0.3 x 13.7 x 4.0	2.24	2.04
0.013	0.3 x 22.9 x 6.0	2.34	2.04
0.0	Calm water	2.54	2.04

TABLE 11. OPTIMUM BOOM PERFORMANCE WITH OIL MAXIMUM "NO LOSS" TOW SPEED (JO 6)

H/L	Wave characteristics H x L x P m x m x secs	Containment critical tow speed* kts	Diversionary critical tow speed* kts
0.111	0.3 x 2.7 x 1.5	0.5	0.5
0.067	0.6 x 9.1 x 3.0	0.92	1.62
0.022	0.3 x 13.7 x 4.0	0.92	1.42
0.0	Calm water	0.92	1.62

+ = failure, * = oil loss

TABLE 12. COMPUTED DIVERSIONARY "NO LOSS" TOW SPEEDS FROM CATENARY "NO LOSS" SPEEDS USING ANGULAR COMPONENT TECHNIQUE (JO 6)

	Wave Condition			Catenary	Diversionary	
Overall angle*	H m	L m	P sec	(Observed) kts	(Calculated) kts	(Observed) kts
23	No wave			0.65	1.66	0.90
23	0.3	13.7	4	0.65	1.66	0.90
23	0.6	9.1	3	0.65	1.66	0.90
24	No wave			0.85	2.07	1.20
24	0.3	13.7	4	0.85	2.07	1.40
24	0.6	9.1	3	0.90	2.19	1.00
24	No wave			0.85	2.07	0.80
24	0.3	13.7	4	0.75	1.83	0.80
24	0.6	9.1	3	0.85	2.07	0.80
24	No wave			0.90	2.19	1.40
24	0.3	13.7	4	0.90	2.19	---
24	0.6	9.1	3	0.90	2.19	1.40
27	No wave			0.50	1.1	1.60
27	0.3	13.7	4	0.60	1.33	1.00
27	0.6	9.1	3	0.85	1.77	1.60
30	No wave			1.00	2.00	1.20
30	0.3	13.7	4	0.90	1.80	1.20
30	0.6	9.1	3	0.50	1.0	0.80
34	No wave			0.90	1.37	0.85
34	0.3	13.7	4	0.70	1.06	0.90
34	0.6	9.1	3	0.70	1.06	0.75
44	No wave			0.40	0.57	0.60
44	0.3	13.7	4	---	---	0.50
44	0.6	9.1	3	0.35	0.50	0.45

*Between booms and current

TABLE 13. OPTIMUM SKIMMER TEST RESULTS (JO 6)

Optimum performance	Oil type	Skimmer type
Maximum Oil Recovery Rate		
$2.54 \times 10^{-3} m^3/s$	Lube	Adjustable Weir
$1.39 \times 10^{-3} m^3/s$	No. 2 Fuel	Floating Suction Head
Maximum Efficiency % Oil in Oil/Water Mix		
99%	Lube	Rotating Disc
99%	No. 2 Fuel	Rotating Disc

TABLE 14. TEST RESULTS - CLEAN WATER HARBOUR BOOM (JO 6)

Test no.	Oil Viscosity cSt @20°C	Oil Distribution Volume m^3	Slick Thk. mm	Tow speed range knots	Height meters	Wave Length meters	Period sec.	Critical tow speed knots	Mode* of failure
1				.75-	1	0	0		1+
2				.1- 1.6	0	0		1.5	SU
3				1.5- 1.75	0	0		1.5	SU
4				0- 1.5	0.3	22.9	6.0	1.3	SU
5				0- 1.2	0.6	9.1	3.0	.9	SU
6				0- 1.5	0.3	13.7	4.0	1.3	SU
7				0- 1.2	0.3	2.7	1.5	0	SP
8	1068	1.14	2.0	0- 1.3	0.3	13.7	4.0	1.3	SH
9	1068	1.51	2.0	0- .8	0.6	9.1	3.0	.8	SH
10	1718	1.33	2.0	0- 1.2	0	0		1.3	SH
11	1994	1.36	2.0	0- 1.3	0.3	13.7	4.0	1.3	SH
				VISCOSITY @ 30°C					
12				.7- 1.3	0	0		1.2	SU
13				.9- 1.2	0.3	13.7	4.0	1	SP
14				.9- 1.2	0.3	22.9	6.0	1	SP
15				.5- .9	0.6	9.1	3.0	.5	SP
16				.3- .5	0.3	2.7	1.5	0	SP
17	405	1.06	2.0	0- 1.1	0	0		.85	SH
18	345	1.56	2.0	0- .9	0.3	13.7	4.0	.9	SH
19	345	1.52	2.0	0- .5	0.6	9.1	3.0	.5	SP
109	238	1.32	2.0	0- 1	0.3	2.7	1.5	0	SP

*Mode of failure = SUbmarining, SPlashover, SHedding, PLaning

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TABLE 15. TEST RESULTS - COASTAL SERVICES T-T BOOM (JO 6)

Test no.	Oil Viscosity cSt @20°C	Oil Distribution Volume m^3	Slick Thk. mm	Tow speed range knots	Waves Height meters	Waves Length meters	Period sec.	Critical tow speed knots	Mode* of failure
1				.5- 1.3	0	0		1	SU
2				.5- 1	0.3	22.9	6.0	.8	SU
3				.5- .9	0.6	9.1	3.0	.7	SU
4				.5- .7	0.3	13.7	4.0	.7	SU
5				0- .5	0.3	2.7	1.5	0	SP
6	223	1.53	2.0	0- 1	0	0		.9	SH
7	227	1.52	2.0	0- .6	0.6	9.1	3.0	.6+	NO
Pl	227	1.52	2.0	0- 1	0	0		.9	SH
8	227	1.33	2.0	0- .7	0.6	9.1	3.0	.7	SH
9	245	1.34	2.0	0- .7	0.3	13.7	4.0	.7	SH
10				.7- 1.1	0	0		1	SU
11				.5- 1	0.3	13.7	4.0	.9	SU
12				0- .8	0.3	2.7	1.5	0	SP
13				.5- .9	0.3	22.9	6.0	.8	SU
14				.5- 1	0.6	9.1	3.0	.8	SU
15				.7- 1	0	0		.94	SU
16				.5- .9	0.6	9.1	3.0	.8	SU
17				.5- 9	0.6	22.9	6.0	.8	SU
18				.5- 1	0.3	13.7	4.0	.94	SU
19				0- .5	0.3	2.7	1.5	.5	SP
20	324	1.32	2.0	0- .9	0	0		.8	SH
				VISCOSITY @ 32°C					
21	385	1.32	2.0	0- .9	0.3	13.7	4.0	.9	SH
22	305	1.32	2.0	0- .8	0.3	22.9	6.0	.8	SH
23	329	1.32	2.0	0- .75	0.6	9.1	3.0	.75	SH

*Mode of failure = SUbmarining, SPlashover, SHedding, PLaning

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TABLE 16. TEST RESULTS - ACME O.K. CORRAL BOOM (JO 6)

Test no.	Oil Viscosity cSt @30^0C	Oil Distribution Volume m^3	Slick Thk. mm	Tow speed range knots	Height meters	Waves Length meters	Period sec.	Critical tow speed knots	Mode* of failure
				DIVERSIONARY					
24				0- 1	0	0		.84	PL
25				0- .1	0.6	9.1	3.0	.84	PL
26				0- 1	0.3	22.9	6.0	.9	PL
27				0- .5	0.3	2.7	1.5	0	SP
28				0- 1	0.3	13.7	4.0	.9	PL
29	406	1.32	2.0	.5- 1	0	0		.8	SH
30	297	1.33	2.0	.5- 1	0.3	13.7	4.0	.8	SH
31	297	1.33	2.0	.5- 1	0.6	9.1	3.0	.8	SH
				CATENARY - Oil Viscosity @35^0C					
33				.5- 2.2	0	0		2.1	PL
34				.5- 2	0.3	13.7	4.0	1.5	PL
35				0- .5	0.3	2.7	1.5	0	SP
36				.5-1.1	0.6	9.1	3.0	.94	SP
37				.5- 2.5	0.3	22.9	6.0	1.75	SP
32	164	1.32	2.0	0- .8	0.3	13.7	4.0	.75	SH
38	1626	1.35	2.0	0- 1	0	0		.84	SH
39	425	1.32	2.0	0- 1	0.6	9.1	3.0	.84	SH
40	381	1.33	2.0	0- 1	0.3	13.7	4.0	.38	SH

*Mode of failure = SUbmarining, SPlashover, SHedding, PLaning

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TABLE 17. TEST RESULTS - PERMAFLOAT, SEA BOOM, 18 PFX (JO 6)

Test no.	Oil Viscosity cSt @33°C	Oil Distribution Volume m³	Slick Thk. mm	Tow speed range knots	Height meters	Waves Length meters	Period sec.	Critical tow speed knots	Mode* of failure
				CATENARY					
41				.5- 2.5	0	0		2.5	SP
42				.5- 2.2	0.3	13.7	4.0	2.1	SP
43				.3- .5	0.3	2.7	1.5	0	SP
44				.50 2	0.6	9.1	3.0	1.5	SP
45				.50 2.5	0.3	22.9	6.0	2.2	PL
46	381	1.33	2.0	.84- 1.1	0	0		.84	SH
47	381	1.32	2.0	.5- 1.1	0.6	9.1	3.0	.9	SH
48	331	1.32	2.0	.84- 1.1	0.3	13.7	4.0	.84	SH
				DIVERSIONARY - VISCOSITY @ 28°C					
49				.5- 2.2	0	0		1.6	PL
50				.5- 1.6	0.3	13.7	4.0	1.5	PL
51				0- .5	0.3	2.7	1.5	0	SP
52				.5- 1.2	0.6	9.1	3.0	1	SP
53				.5- 2.5	0.3	22.9	6.0	1.5	PL
54	267	1.32	2.0	0- 1.6	0	0		1.2	SH
55	124	1.14	2.0	0- 1	0.6	9.1	3.0	1	SH
56	71	1.13	20	0- 1.4	0.3	13.7	4.0	1.4	SH

*Mode of failure = SUbmarining, SPlashover, SHedding, PLaning

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TABLE 18. TEST RESULTS - SLICKBAR MARK VI BOOM (JO 6)

Test no.	Oil Viscosity cSt @37°C	Oil Distribution Volume m^3	Slick Thk. mm	Tow speed range knots	Height meters	Waves Length meters	Period sec.	Critical tow speed knots	Mode* of failure
				DIVERSIONARY					
73				0- 2.2	0	0		.9	PL
74				0- 2.2	0	0		.94	PL
75				0- 1.2	0.3	13.7	4.0	.9	PL
76				0- 1.2	0.3	22.9	6.0	.9	PL
77				0- 1.2	0.6	9.1	3.0	.9	PL
78				0- 1	0.3	2.7	1.5	0	SP
79	140	1.32	2.0	0- 1.5	0	0		.9	SH
80	131	1.32	2.0	0- 1.5	0.6	9.1	3.0	.9	SH
81	131	1.33	2.0	0- 1.5	0.3	13.7	4.0	.9	SH
				CATENARY					
82				0- 2	0	0		1.2	PL
83				0- 2	0.3	13.7	4.0	.8	PL
84				0- 1.2	0.3	22.9	6.0	1	PL
85				0- 1.2	0.6	9.1	3.0	.8	PL
86				0- 1.2	0.3	2.7	1.5	0	SP
87	298	1.32	2.0	0- 1	0	0		.65	SH
88	142	1.32	2.0	0- 1	0.6	9.1	3.0	.65	SH
89	142	1.32	2.0	0- 1	0.3	13.7	4.0	.65	SH

*Mode of failure = SUbmarining, SPlashover, SHedding, PLaning

EPA-287 (Cin.)
(4-76)

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TABLE 19. TEST RESULTS - KEPNER SEA CURTAIN BOOM (JO 6)

Test no.	Oil Viscosity cSt @43°C	Oil Distribution Volume m^3	Slick Thk. mm	Tow speed range knots	Height meters	Waves Length meters	Period sec.	Critical tow speed knots	Mode* of failure
				CATENARY					
57				.5- 2.5	0	0		2	SU
58				0- .7	0.3	2.7	1.5	.5	SP
59				.5- 1.5	0.3	13.7	4.0	1	SP
60				.5- 2	0.3	22.9	6.0	1.8	SU
61				.5- 1.4	0.6	9.1	3.0	1	SP
62	97	1.32	2.0	0- 1.9	0	0		.9	SH
63	97	1.40	2.0	0- .9	0.6	9.1	3.0	.9	SH
64	97	1.32	2.0	0- .9	0.3	13.7	4.0	.9	SH
				DIVERSIONARY - Viscosity @28°C					
65				.25-	1.12	0	0		1.7
66				.7- 2.2	0	0		1.7	SU
67				0- 1	0.3	2.7	1.5	0	SP
68				0- 2.2	0.3	22.9	6.0	1.8	SU
69				0- 2.2	0.6	9.1	3.0	1.5	SU
70	242	1.34	2.0	0- 1.4	0	0		1.4	SH
71	228	1.32	2.0	0- 1.4	0.6	9.1	3.0	1.4	SH/SP
72	228	1.32	2.0	0- 1.4	0.3	13.7	4.0	NO	TC

*Mode of failure = SUbmarining, SPlashover, SHedding, PLaning

EPA-287 (Cin.)
(4-76)

TABLE 20. TEST RESULTS - PACE OIL BOOM (JO 6)

Test no.	Oil Viscosity cSt @29°C	Oil Distribution Volume m^3	Slick Thk. mm	Tow speed range knots	Height meters	Waves Length meters	Period sec.	Critical tow speed knots	Mode* of failure
				CATENARY					
110				0- 2	0	0		1.75	SU
112				0- 1.75	0.6	9.1	3.0	1.5	SP
113				0- 1.5	0.3	22.9	6.0	1.4	SP
111	136	1.32	2.0	0- 2	0	0		.4	SH
114	329	1.32	2.0	0- 1.75	0.6	9.1	3.0	.35	SH/SP
				DIVERSIONARY - Viscosity @38°C					
115				0- 2	0	0		1.64	SU
117				0- 2	0.3	13.7	4.0	1.64	SU
119				0- 2	0.6	9.1	3.0	1.4	SP
121				0- .5	0.3	2.7	1.5	.35	SP
122				0- 2	0.3	22.9	6.0	1.8	SU
116	200	1.32	2.0	0- 1	0	0		.6	SH
118	411	1.32	2.0	0- 1	0.3	13.7	4.0	.5	SH
120	195	1.32	2.0	0- 1	0.6	9.1	3.0	.5	SH

*Mode of failure = SUbmarining, SPlashover, SHedding, PLaning

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TABLE 21. TEST RESULTS - WHITTAKER EXPANDI-BOOM (JO 6)

Test no.	Oil Viscosity cSt @43°C	Oil Distribution Volume m^3	Slick Thk. mm	Tow speed range knots	Height meters	Waves Length meters	Period sec.	Critical tow speed knots	Mode* of failure
				CATENARY					
90				.5- 2	0	0		2+	NO
90R				1- 2.5	0	0		2.5	PL
91				1- 2.5	0.3	13.7	4.0	1.9	PL
91R				1- 2.2	0.3	13.7	4.0	1.9	PL
92				.5- 1	0.3	2.7	1.5	0	SP
93				.5- 2	0.3	22.9	6.0	1.9	PL
94				.5- 2	0.6	9.1	3.0	1.9	PL
95	177	1.32	2.0	0- 1	0	0		.5	SH
96	177	1.32	2.0	0- .84	0.6	9.1	3.0	.84	SH
97	177	1.32	2.0	0- .84	0.3	13.7	4.0	.6	SH
98	10	1.32	2.0	0- 1	0	0		.4	SH
			DIVERSIONARY - Viscosity @39°C						
101				0- 2	0	0		2+	NO
102				0- 2	0.6	9.1	3.0	2+	NO
103				0- 2	0.3	22.9	6.0	2+	NO
106				0- 2	0.3	13.7	4.0	2+	NO
108				0- 2	0.3	2.7	1.5	.5	SP
104	238	1.32	2.0	0- 2	0	0		1.4	SH
104R	238	1.32	2.0	0- 2	0	0		1.6	SH
105	238	1.32	2.0	0- 2	0.6	9.1	3.0	1.2	SH
105R	238	1.32	2.0	0- 2	0.6	9.1	3.0	1.6	SH
107	238	1.32	2.0	0- 2	0.3	13.7	4.0	1	SH
F 2	411	1.32	2.0	0- 2	0.3	2.7	1.5	.4	SP
			CATENARY - Viscosity @28°C						
99	10	1.32	2.0	0- 1	0.3	13.7	4.0	.4	SH
100	10	1.32	2.0	0- 1	0.6	9.1	3.0	.7	SH

*Mode of failure = SUbmarining, SPlashover, SHedding, PLaning

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TABLE 22. TEST RESULTS - SLICKBAR SKIMMERS WITH MARLOW PUMP (JO 6)

Test no.	Oil Viscosity cSt @20°C	Wave Height meters	Wave Length meters	Wave Period sec.	ORR m^3/hr	% Oil	% Water
SKIMMER #1							
46	1910	0	0		.8	43.7	56.3
47	2472	0.6	9.1	3.0	4.1	7.0	93.0
48	2697	0.3	13.7	4.0	.7	35.9	64.1
SKIMMER #2							
70	330	0	0		2.5	61.9	38.1
71	274	0.6	9.1	3.0	2.8	53.0	47.0
72	378	0.3	13.7	4.0	3.1	20.4	79.6
SKIMMER #3							
63	274	0.6	9.1	3.0	4.5	37.5	62.5
64	272	0.3	13.7	4.0	2.6	68.6	31.4
SKIMMER #4, Viscosity @32°C							
8	10	0	0		5.2	22.2	77.8
9	10	0.3	13.7	4.0	1.6	76.1	23.9

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TABLE 23. TEST RESULTS - ACME FLOATING SAUCER SK-39T SKIMMER (JO 6)

Test no.	Oil Viscosity cSt @20°C	Wave Height meters	Wave Length meters	Wave Period sec.	ORR m^3/hr	% Oil	% Water
29	1697	0	0		4.3	27.3	72.7
54	282	0	0		1.4	57.1	42.9
55	303	0.6	9.1	3.0	2.9	41.6	58.4
56	343	0.3	13.7	4.0	3.7	56.7	43.3

TABLE 24. TEST RESULTS - B.P. VIKOMA KOMARA MINISKIMMER WITH SPATE PUMP (JO 6)

Test no.	Oil Viscosity cSt @26°C	Wave Height meters	Wave Length meters	Wave Period sec.	ORR m^3/hr	% Oil	% Water
118	367	0	0		1.4	99+	0
120	556	0.6	9.1	3.0	1.9	84.0	16.0
5	570	0	0		.9	76.1	23.9
6	18	0	0		2.4	99+	0

EPA-287 (Cin.)
(4-76)

TABLE 25. TEST RESULTS - COASTAL SERVICES SLURP SKIMMER WITH SPATE AND HOMELITE PUMPS (JO 6)

Test no.	Oil Viscosity cSt @20°C	Wave Height meters	Wave Length meters	Wave Period sec.	ORR m^3/hr	% Oil	% Water
SPATE PUMP							
80	327	0.6	9.1	3.0	1	81.4	18.6
1	513	0	0		1.1	29.0	71.0
109	476	0	0		1.3	14.3	85.7
2	21	0	0		.96	6.0	94.0
3	9	0	0		.92	6.0	94.0
4	10	0	0		.99	6.0	94.0
HOMELITE PUMP							
21	2295	0.3	13.7	4.0	.56	48.6	51.4
22	1987	0.3	22.9	6.0	1.3	46.5	53.5
23	1679	0.6	9.1	3.0	.59	66.7	33.3
81	293	0.3	13.7	4.0	1.1	85.3	14.7

TABLE 26. TEST RESULTS - KAISER OELA III SWISS OIL SKIMMER WITH SPATE AND HOMELITE PUMPS (JO 6)

Test no.	Oil Viscosity cSt @20°C	Wave Height meters	Wave Length meters	Wave Period sec.	ORR m^3/hr	% Oil	% Water
			HOMELITE PUMP				
11	908	0.3	13.7	4.0	1.3	46.7	53.3
17	3258	0	0		1.1	51.5	48.5
19	2123	0.6	9.1	3.0	1.7	49.8	50.2
			SPATE PUMP				
116A	676	0	0		1.0	61.5	38.5
116B	393	0	0		.85	74.6	25.4

In general, the skimmer's performance was affected by oil viscosity. The rotating disc type skimmer performance strongly increased with viscosity. The self-adjusting weir and floating suction head registered a slight increase with viscosity, while the adjustable weir performance remained unaffected.

Also, the oil recovery capacity was very much dependent on the other components in the skimming system--the connection hose (diameter and length), the type of pump (diaphragm or axial flow) and the discharge hose (diameter and length). For the viscous oils, hose diameters and lengths, 7.6 cm and 15.2 m worked best for the pumps involved. Also, the diaphragm pumps performed much better in viscous oils than axial flow or centrifugal pumps.

There was no clear correlation of skimmer performance and wave conditions for the waves observed. In some cases, there seemed to be a slight improvement and in other cases a slight decrease in performance with certain waves. In general, these differences were small enough to be explained by the inaccuracies of test measurement.

JOB ORDER NO. 7 - U.S. NAVY

Dates 9-25 June 1975

Customer
Civil Engineering Laboratory
U.S. Naval Construction Battalion Center
Port Hueneme, CA 93043 805-982-5435

Device
DIP 3001 Skimmer
JBF Scientific Corporation
2 Jewel Drive
Wilmington, MA 01887 617-657-4170

Bennett Boom
Bennett Pollution Controls, Ltd.
119 Charles Street
North Vancouver, B.C., V7H 1S1, Canada 604-929-5451

SwRI Boom
Southwest Research Institute
P.O. Drawer 28510
San Antonio, TX 78284 512-684-5111

Description of Program

The test program was carried out on the USN DIP 3001 Oil Recovery System in June 1975 at OHMSETT, under calm conditions and in waves. Various adjustments were made on the skimmer to establish optimum methods of operating the recovery system. The trends in the data, in general, indicate that the recovery system operated most efficiently at 1 knot without concentration sweeps. The average was 85%. This value as well as the remaining data, it is reasoned, could be as much as 20% in error due to inaccuracies in the test procedures. It was concluded therefore that it is not

TABLE 27. TEST RESULTS - DIP 3001 SKIMMER (JO 7)

Test no.	Tow speed kts	Belt speed kts	Back plate mm	Sweeps	Wave H. m	RE %
16	2	5	12.7	Up	0	49
17	2	4	12.7	Up	0	44
20	2	5	12.7	Up	0	29
12	2	5	57.2	Up	0	36
14	2	4	57.2	Up	0	45
15	2	4	98.4	Up	0	15
30	2	5	139.7	Down	0.3R*	33
31	2	5	139.7	Down	0.6R	24
35	1.5	1.5	209.6	Up	0	72
37	1.5	1.5	209.6	Down	0	56
38	1.5	1.5	209.6	Down	0.3R	30
23	1	5	98.4	Down	0.3R	76
26	1	5	98.4	Down	0.3R	55
24	1	5	98.4	Down	0.6R	67
25	1	5	98.4	Down	0.6R	65
28	1	5	139.7	Down	0.15R	59
27	1	5	139.7	Down	0.3R	62
21	1	5	57.2	Down	0.6	72
22	1	1	57.2	Down	0.3R	65
34	1	1	209.6	Up	0	109
33	1	1	209.6	Up	0.3R	53
32	1	1	209.6	Up	0.6R	45
21	1	5	12.7	Down	0	72
21r**	1	5	57.2	Down	0	72
1	1	5	139.7	Down	0	79
2	1	5	139.7	Down	0	66
36	1	1	209.6	Down	0	54

*R = regular wave
**r = repeat

possible to make critical adjustments for optimum operation until more accurate test procedures are employed. It is recommended that another series of tests be performed using better procedures. An outline of these procedures and the proposed test program are included.

Conclusions

In general, the results indicate that the DIP 3001 Oil Recovery System operated most efficiently at 1 knot without concentration sweeps. The average of 7 runs was 85%. This value as well as the remaining data, it is reasoned in the report, could be as much as 20% in error due to inaccuracies in the test procedures.

The trends of the data indicate that there are significant decreases in efficiency when the concentration sweeps are in operation and also with increases in towing speed and wave heights. These trends, however, are sometimes contradicted without rational explanation even when belt speed and back plate opening are not varied. For example, when comparing run 26 with runs 24 or 25, the efficiency increases approximately 10% when the random wave inputs are doubled (0.3 m Regular to 0.6 m Regular) for the same belt speed and back plate opening. These and other contradictions that can be seen from examining the results lead to the explanation that there must be inaccuracies in the test procedures which mask the effects of changing parameters of the test conditions and adjusting the variables of the recovery system.

It was concluded, therefore, that it is not possible to adjust belt speed and back plate openings for more efficient operation based on the test results obtained. What is needed to determine these adjustments and/or improving the design of the system are:

1. Methods of observing the recovery process underwater as adjustments are made on components of the recovery device and as the environment conditions and tow speeds are varied.
2. More accurate methods of deploying and confining the oil to obtain uniform slick thickness.
3. A more precise method for defining the wave system produced.

JOB ORDER NO. 8 - U.S. COAST GUARD

Dates 3-23 July 1975

Customer Office of Research and Development
U.S. Coast Guard
G-DMT-4/TP54
Washington, DC 20593 202-426-1023

Devices Cyclonet D-050 Skimmer
Alsthom Atlantic, Inc.
Pollution Control Dept.
441 Gravier Street
New Orleans, LA 70130 504-581-5636

DIP 3001 Skimmer
JBF Scientific Corporation
2 Jewell Drive
Wilmington, MA 01887 617-657-4170

MARCO Class I Skimmer
MARCO Pollution Control
2300 West Commodore Way
Seattle, WA 98199 206-285-3200

OSI 125 Skimmer
Ocean Systems, Inc.
11440 Isaac Newton Industrial Square
North Reston, VA 22010 703-471-1310

Lockheed R2003 Skimmer
Lockheed Missiles and Space Co., Inc.
P.O. Box 504, Bldg. 570
Sunnyvale, CA 94806 408-988-0906

Description of Program

Sponsored by the U.S. Coast Guard, this project endeavored to further develop a standard test plan for oil skimmers, to evaluate selected devices for purchase as operational equipment, to evaluate the performance of these units in fast current environments and to familiarize Coast Guard Strike Teams with their use. The Cyclonet D-050, JBF 3001, Lockheed R2003, MARCO Class I, and OSI 125 were evaluated with No. 2 fuel oil and a lubricating stock in a variety of surface conditions at selected tow speeds. Additional information is available from LCDR C. Doherty, U.S. Coast Guard (G-DMT-4/TP54), Washington, DC 20593.

JOB ORDER NO. 9 - U.S. COAST GUARD

Dates 25 July - 8 August 1975

Customer Office of Research and Development
U.S. Coast Guard
G-DMT-4/TP54
Washington, DC 20593 202-426-1023

Devices ODI Type A, B, and C Skimmer/Booms
Offshore Devices, Inc.
Summit Industrial Park, Bldg. 43
Peabody, MA 01960 617-581-6404

Report Milgram, J.H. and R.A. Griffiths. Combined Skimmer-Barrier High Seas Oil Recovery System. In: Proceedings of the 1977 Oil Spill Conference. American Petroleum Institute, New Orleans, Louisiana, 1977. pp. 375-379 (Ref. 40).

Description of Program

The modified third generation high seas oil containment barrier with weirs located in its apex and connected to diaphragm pumps was evaluated by the U.S. Coast Guard. Three configurations of the skimmer-barrier were evaluated for recovery efficiency and recovery rate with two test oils in a selection of surface conditions, oil slick thicknesses, and tow speeds. Performance plots summarizing the results of this program were utilized to determine optimum operating conditions of the system. Additional information is available from LCDR C. Doherty, U.S. Coast Guard (G-DMT-4/TP54), Washington, DC 20593.

JOB ORDER NO. 10 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	12-16 May 1975	
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817	201-321-6600
Device	High Current Boom Shell Development Co. E-1340 West Hollow Research P.O. Box 1380 Houston, TX 77001	713-493-7094
Report	Ayers, R.R. A Rigid, Perforated Plate Oil Boom for High Currents. EPA-600/2-76-263, U.S. Environmental Protection Agency, 1976 (Ref. 2).	

Description of Program

Under the sponsorship of the U.S. EPA, the Shell Development Company developed a rigid, modular boom and tested it at OHMSETT in 1975. The device was made up of 2.4 m long rigid sections (modules) joined together side by side. These modules included a baffle upstream of a conventional flat plate boom thereby creating a flow-sheltered region for oil thickening. The device was tested in both the diversionary (45° to tow direction) and containment (90°) configurations with a lubricating stock and No. 2 fuel oil in a variety of surface conditions. Technical report EPA-600/2-76-263 is available from NTIS.

Conclusions

This high-current boom capable of diverting No. 2 and No. 4 fuel oil at 3 knots with typically less than 15 percent of the applied oil loss under the boom. Boom design depends upon an inclined, 50 percent perforated-plate baffle just upstream of a solid vertical-plate barrier. The flow-sheltered region between the baffle and the barrier has a perforated plate as a bottom, slowing the exiting water. In addition, horizontal flow control plates immediately behind the inclined baffle reduce water downflow and minimize turbulence.

TABLE 28. SHELL HIGH CURRENT BOOM TESTS AT OHMSETT (JO 10)

Run no.	Boom angle[a] (deg.)	Test oil	Tow velocity (kts)	Contact time[b] (sec)	Wave Height (m)	Wave Period (sec)	Oil applied m^3	Equivalent thk.[c] (mm)	Oil retained or diverted (m^3)	%
1	45	Sun 75	2.0	75	---	---	0.73	1.0	---	100[d]
2	45	Sun 75	3.0	54	---	---	0.79	0.8	---	90[d]
3	45	Sun 75	3.5	60	---	---	1.44	0.9	1	70
4	45	Sun 75	2.5	60	0.15	3	1.06	0.9	1	94
5	45	Sun 75	3.25	60	0.15	3	1.13	0.9	0.97	86
6	45	Sun 75	3.0	60	0.2	2	1.14	0.9	1	88
7[e]	90	Sun 75	2.3	60	---	---	1.4	1.6	0.81	85
8[e]	90	Sun 75	2.2	60	0.15	3	1.28	1.6	1.08	84
9	45	No. 2	3.0	60	---	---	1.53	1.5	---	87[d]
10	45	No. 2	3.0	60	0.2	2	1.62	1.4	---	85[d]

[a] Angle is between boom and tank sidewall.
[b] Time boom under tow is in contact with test oil.
[c] Based on 9.1 m slick width.
[d] Estimated.
[e] Rotating mooring cables caused boom to pitch downward, then the increased flow sumberged the stern at speeds in excess of 2.3 knots. This can be easily corrected.

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TABLE 29. TWO-DIMENSIONAL BOOM TOW TESTS - FOUR-FOOT WIDE SECTION (JO 10)

Run no.	Boom angle[a] (deg.)	Test oil	Tow velocity (kts)	Contact time[f] (sec)	Wave Height[d] (m)	Wave Period (sec)	Oil applied m^3	Equivalent thk.[e] (mm)	Oil retained or diverted (m^3)	%
1	90	No. 2	2.35		---	---	73	2.0	67	91.0
2	90	No. 2	2.39		---	---	78	2.1	70	89.6
3	90	No. 2	2.94		---	---	70	1.9	60	85.2
4	90	No. 2	2.94		---	---	62	1.7	53	85.2
5	90	No. 2	2.99		0.15	---	65	1.8	34	51.9
6	90	No. 2	1.31		---	---	83	2.2	82	99.0
7	90	No. 2	2.19		0.15	---	73	2.0	48	65.8
8	90	No. 2	2.28		0.15	---	64	1.7	41	64.2
9	90	No. 2	1.72		0.15	---	94	2.5	60	64.1[a]
10[b]	90	No. 2	2.19		---	---	61	1.6	58	96.1
11	90	No. 2	1.69		0.15	---	82	2.2	65	79.2
12	90	Navy spec	1.75		0.15	---	83	2.2	36	44.0
13	90	Navy spec	2.26		0.15	---	75	2.0	22	29.4
14	90	Navy spec	2.28		---	---	80	2.2	31	38.4
15	90	Navy spec	1.79		---	---	78	2.1	63	80.0
16[b]	90	Navy spec	2.29		---	---	63	1.7	52	82.3
17	90	Navy spec	1.37		---	---	101	2.7	94	92.1
18[c]	90	Navy dis[g]	2.28		---	---	80	2.1	37	45.9

a. Detectable loss around sides made this high.
b. "Preloaded" run using 0.06 m^3 oil from previous run. This was run to show amount lost through bottom holes.
c. Baffles were removed; a straight vertical board was placed at the same 14" draft to see how much loss occurred when baffles are not used.
d. Wave steepness, H/L = 1/40.
e. Calculation based on slick 1.2 m wide.
f. Time boom under tow is in contact with test oil.
g. Navy distillate oil has the same properties as No. 2 fuel oil.

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TABLE 30. DIVERSION TEST OF THE SHELL HIGH CURRENT BOOM, HOUSTON TANK (JO 10)

Run-angle deg.	Knots	Wave height (m)	Steepness ratio (H/L)	Equiv. slick thickness (mm)	Percent oil loss
1-15	2.4	---	---	2.3	2.6
1-30	2.4	---	---	2.5	1.3
1-45	2.5	---	---	2.2	0.8
1-60	2.5	---	---	2.2	3.0
2-15	3.0	---	---	1.9	2.0
2-30	2.9	---	---	1.8	1.1
2-45	3.0	---	---	1.9	2.6
2-60	3.0	---	---	1.8	1.3
3-60	3.6	---	---	1.6	0.9
4-15	2.4	0.15	0.05	2.2	1.5
4-45	2.4	0.15	0.05	2.2	2.8
5-45[g]	2.5	---	---	---	---
6-45[g]	2.6	0.15	0.05	2.0	9.6
7-45[g]	2.5	0.3	0.05	2.0	9.1
8-45[g]	2.4	---	---	2.4	3.5[h]
9-45	2.5	0.3	0.05	1.5	4.3[i]
10-45	2.5	0.3	0.05	1.5	9.6[i]
11-45	2.5	0.15	0.05	1.3	6.0[i]
12-45	2.5	---	---	1.3	4.4[i]
13-45	2.5	---	---	1.6	6.4[j]

Notes:

a. Five 1.2 m wide boom sections were used.
b. The transverse direction is 0°, the tow direction is 90°.
c. Oil flow from the nozzle was begun at the start of the 22.86 m tow line.
d. Navy distillate was used in the test 25°C.
e. Percent oil loss based on comparison of the total volume lost with the total volume applied.
f. Center of nozzle in line with center of boom, except as noted.
g. Center of nozzle moved from center of boom 1.2 m toward leading edge of boom.
h. Oil applied at starting point.
i. Oil applied 3 m before starting point.
j. Oil applied 7.62 m before starting point.

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The boom profile is built into 2.4 m wide rigid sections and linked together like a floating marina dock.

A primary application for this high-current device is its use as a permanently deployed diversionary boom, perhaps downstream of an oil loading/unloading dock. A standard skimmer, used in the flow-sheltered region of the boom to recover oil accumulated, will increase the boom's effectiveness.

Boom modules can be attached to vessels of opportunity for use as a temporary emergency skimmer. They can also be placed in a specially designed vessel and used as a permanent inshore skimmer.

The boom design is based on extensive full-scale experimentation and testing at the Shell current and wave tanks. Principal confirming tests were conducted at OHMSETT.

JOB ORDER NO. 11 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates: 16 September - 4 November 1975

Customer:
Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 — 201-321-6600

Devices:
U.S.C.G. Prototype High Seas Boom
Offshore Devices, Inc.
Summit Industrial Park, Bldg. 43
Peabody, MA 01960 — 617-581-6404

Harbour Boom
Clean Water, Inc.
P.O. Box 1002
Toms River, NJ 08753 — 201-341-3600

Permafloat Sea Boom, 18 PFX
B.F. Goodrich Sea Products, Inc.
430 S. Main Street
Cohasset, MA 02025 — 617-383-6000

Reusable Sorbent Cube Skimmer
Seaward International, Inc.
6269 Leesburg Pike
Falls Church, VA 22033 — 703-534-3500

ORS-125 Skimmer
Ocean Systems, Inc.
11440 Isaac Newton Industrial Square
North Reston, VA 22010 — 703-471-1310

DIP 1002 Skimmer
JBF Scientific Corporation
2 Jewel Drive
Wilmington, MA 01887 617-657-4170

Kaiser OELA-III Swiss Oil Skimmer
Industrial & Municipal Engineering (IME)
P.O. Box N
U.S. Route 34 East
Galva, IL 61434 309-932-2036

Rigid Manta Ray Skimmer, 2.5 mm
Slickbar, Inc.
P.O. Box 139
250 Pequot Avenue
Southport, CT 06490 203-255-2601

Mark II-D Skimmer
Oil Mop, Inc.
P.O. Drawer P
Engineers Road
Belle Chasse, LA 70037 504-394-6110

Report

McCracken, W.E. and S.H. Schwartz. Performance Testing of Spill Control Devices on Floatable Hazardous Materials. EPA-600/2-77-222, U.S. Environmental Protection Agency, 1977 (Ref. 39).

Freestone, F.J., W.E. McCracken, and J.P. Lafornara. Performance Testing of Several Oil Spill Control Devices on Selected Floatable Hazardous Materials. In: Proceedings of 1976 National Conference on Control of Hazardous Material Spills, New Orleans, Louisiana. pp. 326-332. (Ref. 23).

Description of Program

The U.S. EPA and U.S. Coast Guard evaluated selected oil spill control equipment for use on spills of floatable hazardous materials. The fluids used were octanol, dioctyl phthalate, and naphtha. These materials were selected on the basis of toxicity and facility compatibility. It was found that equipment performance was directly related to the physical properties (i.e., specific gravity, interfacial tension, surface tension, and viscosity) of the test fluids. A 16 mm color, sound movie entitled, "Performance Testing of Spill Control Devices on Floatable Hazardous Materials," was produced along with a report (EPA-600/2-77-222) and is available from NTIS.

Conclusions

The following conclusions were drawn from evaluation of the test data and observations of equipment performance, during this project's tests involving hazardous materials (HM) and previous tests with oil conducted under Mason & Hanger Job Order No. 6.

1. Performance of the equipment is directly relatable to the physical properties of the test fluids, which points to the need to define the capability to control, define, or process the various types of oil and/or HM released during spills for each type of device.

2. Performance of the equipment, when used on the HM, did not vary substantially from performance when tested on oils of similar physical properties under the same conditions.

3. The chemical properties of the HM must first be analyzed in terms of equipment operator safety, equipment durability and methods for its separation from water.

Boom Tests

The effect of HM specific gravity on boom performance was defined for the three chemicals tested. Head wave shedding and subsequent entrainment was the primary mode of failure: a phenomenon directly related to droplet formation and the relative velocity between the slick and the tank water. Boom performance (maximum tow speed before HM loss) increased with Naphtha, pointing to a significant relationship between specific gravity and boom maximum tow speed. Test fluids of relatively high specific gravity tended to become entrained via droplet formation and shedding loss occurred at the lower tow speeds in both the catenary and diversionary configurations.

Without waves, containment and diversionary success was limited when the booms were confronted with 1 mm thickness of dioctyl phthalate (DOP). The primary mode of failure was shedding, a phenomenon directly related to droplet formation and subsequent entrainment. Reviewing the comparative physical properties of test fluids, it can be noted that the difference between tank water and test fluid specific gravity was lowest when considering DOP (0.0345) and highest with Naphtha (0.2995). Boom performance increased with Naphtha pointing to a significant relationship between specific gravity and boom maximum tow speed. Test fluids of relatively high specific gravity tended to become entrained as the result of droplet formation and shedding loss occurred at lower tow speeds in both the catenary and diversionary configuration.

Stationary Skimmer Tests

Stationary skimmer performance was found not to be dependent upon the physical properties of the test fluids nor the wave conditions tested. Three different types of stationary skimmers were tested: floating suction head, self-adjusting weir and oleophilic rope types.

The floating suction head skimmer performed slightly better with the more viscous DOP (67.5 cSt) than with less viscous HM under a calm surface condition. When waves were introduced, however, the DOP tended to become mixed into the water column. Under this condition, the performance of the floating suction head skimmer was optimized with Naphtha. It is interesting to note that except with DOP, the nominal 0.6 m harbor chop did not significantly affect recovery rate.

The self-adjusting weir-type skimmer exhibited recovery efficiencies approaching 40% when tested with DOP and a calm surface condition. As with the floating suction head skimmer, efficiency was maximized with the higher density HM. When confronted with the wave condition, the total mixture recovery rate increased as more water was skimmed, but recovery efficiency dropped.

The third stationary design characteristic studied was the oleophilic rope type skimmer. Recovery efficiency approached 100% with DOP and a calm surface condition. Performance in waves was optimized near 80% recovery efficiency. Hydrodynamic forces were somewhat overcome by the adsorption force on the test fluid by the oleophilic rope.

Advancing Skimmer Tests

Similar to the stationary skimmers, the advancing skimmers were found to have a strong relationship between their performance and the physical properties of the HM and the design features and controls of each device. Two types of advancing skimmers were tested: dynamic inclined (non-absorbing) belt (DIP-1002) and floating weir box (ORS-125).

The DIP-1002 skimmer was tested with the following controlled settings:

1. Belt speed = 2.42 kt
2. Tow speed = 0.5 to 2.5 kt
3. Notch opening = 1.9 cm
4. Slick width = 1.52 m
5. Slick thickness = 2 mm
6. Tank surface condition = calm

The tow speed at which maximum performance occurred was dependent upon HM density. HM recovery rate was optimized for each test fluid with respect to increasing tow speed above 0.5 kt. The lower density Naphtha was best recovered at the relatively high tow speed of 2.25 kts. Optimum recovery rate performance with DOP occurred at the lower tow speed of 0.5 kt. Except for DOP, the maximum recovery rates of all test fluids were comparable and it is possible that this recovery rate (approximately 4.7 m^3/hr) may have been reached with DOP at tow speeds lower than 0.5 kt. Since speeds less than 0.5 kt are unacceptable for field use conditions, performance at these speeds was not considered of interest to the overall test program.

Since the intent of the dynamic inclined belt is to induce a flow velocity relative to the test fluids, a critical balance of belt speed to tow speed must be established for each given test fluid. For those fluids that tend to form large diameter droplets upon breakaway (DOP) and have a longer rise time, collection increases at lower current speeds because the droplets must rise into the oil collection well. As tow speed increases test fluid droplets rise behind the collection well and are drawn through the backplate opening and out behind the device. This was evidenced through performance data as well as visual observation. In the case of the low density Naphtha, it was possible to establish a higher flow velocity and successful collection since the rise time is faster. In fact, higher flow velocities were required to move the test fluid to the collection well.

TABLE 31. TEST RESULTS USCG PROTOTYPE HIGH SEAS BOOM (JO 11)

Test no.	Type	Visc, cSt @ ^{0}C	Dist. vol, m^3	Tow speed range, kt	Wave H x L x P m x m x s	Critical tow speed kts	Mode of* failure
			15^{0}C - CATENARY				
S-1				0-1.5	0x0	1.0	SU
S-2				0-1.0	0.6 x 9.1 x 3	0.35 (0.84)	SP (SU)
7	Naphtha	6.5	1.32	0-1.0	0x0	0.9	WA
7R	Naphtha	6.5	1.32	0-1.0	0x0	0.9	WA
8	Naphtha	6.5	1.32	0-1.0	0.6 x 9.1 x 3	0.4	WA
7R^2	Naphtha	6.5	1.32	0-1.0	0x0	0.9	WA
S-3				0-1.0	0.3 HC	0.9	SU
6	Naphtha	6.5	1.32	0-1.0	0.3 HC	0.1	WA
4	Octanol	13.7	1.32	0-1.25	0x0	0.4 (1.0)	SH (WA)
4R$_2$	Octanol	13.7	1.32	0-1.25	0x0	0.4	SH
4R^2	Octanol	13.7	1.32	0-1.25	0x0	0.4	SH

*Modes of failure = SUbmarining, SPlashover, WAshover, SHedding, PLaning

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TABLE 32. TEST RESULTS CLEAN WATER HARBOUR BOOM (JO 11)

Test no.	Type	Visc, cSt @ °C	Dist. vol, m^3	Tow speed range, kt	Wave H x L x P m x m x s	Critical tow speed kts	Mode of* failure
				15°C - CATENARY			
S-1				0-2	0x0	1.75	PL
7	Naphtha	7.0	1.32	0-1	0x0	0.9	SH
6	Naphtha	7.0	1.32	0-1.5	0.3 HC	0.75	SP
ST-1				0-1	0.6 HC	0.7	SP
8	Naphtha	7.0	1.32	0.0.75	0.6 x 9.1 x 3.0	0.6	SH
7R	Naphtha	7.0	1.32	0-1.2	0x0	0.9	SH
3	Octanol	13.6	1.32	0-1	0x0	0.75	SH
4	Octanol	13.6	1.32	0-0.75	0.6 x 9.1 x 3.0	0.3	SH
1	DOP	80.1	1.32	0-0.5	0x0	0.25	SH
2	DOP	80.1	1.32	0-1	0.6 x 9.1 x 3.0	0.2	SH
				16°C - DIVERSIONARY			
S-3				0-2	0.3 HC	0 (2)	SP (SU)
1	DOP	72.3	1.32	0-1	0x0	0.3	SH
2	DOP	72.3	1.32	0-0.5	0.6 x 9.1 x 3.0	0.1 (0.1)	SP (SH)
1R	DOP	72.3	1.32	0-1	0x0	0.3	SH
7	Naphtha	7.3	1.32	0-2	0x0	1.6	SH
7R$_2$	Naphtha	7.3	1.32	0-2	0x0	1.6	SH
7R^2	Naphtha	7.3	1.32	0-2	0x0	1.6	SH
8	Naphtha	7.3	1.32	0-2	0.6 x 9.1 x 3.0	0.4 (1.2)	SP (SH)

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TABLE 32. (Continued)

Test no.	Type	Visc, cSt @ °C	Dist. vol, m^3	Tow speed range, kt	Wave H x L x P m x m x s	Critical tow speed kts	Mode of* failure
			17°C - CATENARY				
7R	Naphtha	6.5	1.32	0-1.2	0x0	0.9	SH
8	Naphtha	6.5	1.32	0.1.2	0.6 x 9.1 x 3	0 (0.8)	SP (SH)
8R	Naphtha	6.5	1.32	0-1.2	0.6 x 9.1 x 3	0 (0.8)	SP (SH)
			DIVERSIONARY				
S-1				0-2.25	0x0	1.9	PL
4	Octanol	13.4	1.32	0-2	0x0	1.5	SH
4R	Octanol	13.4	1.32	0-2	0x0	1.7	SH
4R^2	Octanol	13.4	1.32	0-2	0x0	1.5	SH
S-2				0-2.5	0.6 x 9.1 x 3	0.3 (1.9)	SP (SU)
3	Octanol	13.4	1.32	0-1	0.6 x 9.1 x 3	0.3 (0.9)	SP (SH)

*Mode of failure = SUbmarining, SPlashover, WAshover, SHedding, PLaning

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TABLE 33. TEST RESULTS PERMAFLOAT SEABOOM, 18PFX (JO 11)

Test no.	Type	Visc. cSt @ °C	Dist. vol. m^3	Tow speed range, kt	Wave H x L x P m x m x s	Critical tow speed kts	Mode of* failure
			16°C - CATENARY				
S-1				0-2.5	0x0	2	PL
S-2				0-1.0	0.6 HC	0	SP
S-3				0-2.0	0.3 HC	0.75 (1.7)	SP (PL)
3	Octanol	14.0	1.32	0-0.7	0x0	0.5	SH
4	Octanol	14.0	1.32	0-0.5	0.3 HC	0	SP
3R	Octanol	14.0	1.32	0-0.5	0x0	0.5	SH
S-4				0-1.6	0.6 x 9.1 x 3	1.5	PL
5	Octanol	14.2	1.32	0-0.6	0.6 x 9.1 x 3	0.5	SH
1	DOP	79.2	1.32	0-0.3	0x0	0.2	SH
2	DOP	79.2	1.32	0-0.5	0.6 x 9.1 x 3	0	SP
7	Naphtha	6.5	1.32	0-1.25	0x0	0.9	SH
			DIVERSIONARY				
4	Octanol	13.3	1.32	0-1.0	0x0	0.7	SH
$4R_2$	Octanol	13.3	1.32	0-1.0	0x0	0.7	SH
$4R^2$	Octanol	13.3	1.32	0-1.0	0x0	0.7	SH
3	Octanol	13.3	1.32	0-0.75	0.6 x 9.1 x 3	0.25	SP
7	Naphtha	7.1	1.32	0-1.5	0x0	1.1	SH
$7R_2$	Naphtha	7.1	1.32	0-1.5	0x0	1.1	SH
$7R^2$	Naphtha	7.1	1.32	0-1.5	0x0	1.0	SH
8	Naphtha	7.1	1.32	0-1.25	0.6 x 9.1 x 3	0.9	SP
S-3				0-0.5	0.3 HC	0 (0.3)	SP (SU)
6	Naphtha	7.1	1.32	0-0.5	0.3 HC	0	SP

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TABLE 33. (Continued)

Test no.	Type	Visc. cSt @ ^{o}C	Dist. vol. m^3	Tow speed range, kt	Wave H x L x P m x m x s	Critical tow speed kts	Mode of* failure
				15^{o}C - CATENARY			
3	Octanol	13.7	1.32	0-1.25	0.6 x 9.1 x 3	0.4	SH
1	DOP	74.9	1.32	0-0.5	0x0	0.2	SH
1R	DOP	74.9	1.32	0-0.5	0x0	0.2	SH
2	DOP	74.9	1.32	0-0.5	0.6 x 9.1 x 3	0.3 (0.45)	SP (SH)
				DIVERSIONARY			
S-1				0-1.5	0x0	1.25	SU
S-2				0-1.5	0.6 x 9.1 x 3	0.75 (1.10)	SP (SU)
1	DOP	74.9	1.32	0-0.75	0x0	0.25	SH
2	DOP	74.9	1.32	0-0.50	0.6 x 9.1 x 3	0.15 (0.1)	SP (SH)
1R	DOP	74.9	1.32	0-1.5	0x0	0.3 (1.25)	SH (SU)

*Mode of failure = SUbmarining; SPlashover, WAshover, SHedding, PLaning

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TABLE 34. TEST RESULTS REUSABLE SORBENT CUBE SKIMMER (JO 11)

Test no.	Type	Visc. cSt @ 19°C	Wave	Fluid dist. m^3	Sorbent density Rec. kg/m^3	Sorbent density Regen. kg/m^3	Broad. rate m^3/hr	Broad. vol. m^3	Regen. ten. mPa	ORR m^3/hr	Test fluid %	TE %
1	DOP	78.8	0x0	0.10	603.4	116.5	17	0.20	2.01	4.7	73.1	65.6
P 1	DOP	78.8	0.3 HC	0.17	592.4	116.6	19	0.34	2.14	6.2	72.6	73.7
P 2	DOP	78.8	0.3 HC	0.17	733.2	101.4	13	0.20	2.24	6.1	86.3	62.4
P 3	DOP	78.8	0.3 HC	0.09	737.7	171.6	10	0.07	2.21	2.7	46.3	16.7
P 4	DOP	78.8	0.3 HC	0.15	692.3	1121.7	15	0.24	2.14	5.7	87.2	77.8
P 6	DOP	78.8			Run aborted							
P 6	DOP	78.8	0.3 HC	0.12	841.6	145.9	10	0.17	2.07	5.2	79.9	76.5
2a	DOP	78.8	0.6 HC	0.13	595.1	155.5	18	0.29	2.07	5.5	76.5	79.1
2b	DOP	78.8	0.6 HC	0.12	728.4	137.8	15	0.19	2.07	5.1	74.2	68.0
7	Nap	6.5	0x0	0.14	663.0	144.3	12	0.19	2.34	5.2	85.9	75.4
8	Nap	6.5	0.6 HC	0.13	566.3	152.8	12	0.20	2.34	4.4	77.2	60.2
6a	Nap	6.5	0.3 HC	0.13	549.3	123.2	12	0.20	2.41	4.9	87.6	72.8
6b	Nap	6.5	0.3 HC	0.12	634.3	144.6	9	0.14	2.24	3.9	90.1	61.0
4	Oct	12.4	-0-	0.13	866.3	166.0	14	0.22	2.41	7.3	48.6	62.0
3R	Oct	12.4	0.6 HC	0.13	777.2	132.8	17	0.30	2.59	7.8	40.1	57.5
5	Oct	12.4	0.3 HC	0.11	854.3	156.7	12	0.20	2.41	6.2	50.9	69.6

Harvest belt speed equal 2 knots

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TABLE 35. TEST RESULTS ORS-125 SKIMMER (JO 11)

Test no.	Type	Visc. cSt @ 21°C	Dist. rate m^3/hr	Slick thk. mm	Tow speed kts	Air supply pump kPa	ORR m^3/hr	TE %	RE %
6	Nap	6.69	13	4.8	1.0	296	0	0	0
7	Nap	6.69	22	3.9	2.0	296	0	0	0
8	Nap	6.69	19	4.5	1.5	290	0	0	0
ST-1	Nap	6.69	26	3.1	3.0	296	0	0	0
1	DOP	93.70	11.5	4.1	1.0	296	1.1	9.6	6.0
2	DOP	93.70	18	4.4	1.5	296	0.79	4.4	4.3
3	DOP	93.70	6.5	4.6	0.5	296	3.9	61.4	21.6
P 3	DOP	93.70	5.8	4.1	0.5	276	5.1	89.6	27.8
P 4	DOP	93.70	5.8	4.1	0.5	276	5.2	92.0	28.6
P 5	DOP	93.70	5.8	4.1	0.5	276	4.0	70.0	22.3
P 2	DOP	93.70	5.8	4.2	0.5	276	5.1	86.2	27.8
P 1	DOP	93.70	5.8	4.1	0.5	276	4.6	80.4	25.5
4	DOP	93.70	9.0	4.4	0.75	276	1.3	14.5	7.2
5	DOP	93.70	3.2	4.6	0.25	276	1.4	45.7	8.0
9	Oct	13.30	14.0	4.0	1.25	221	2.3	16.9	14.3
$10R_2$	Oct	13.30	21.0	4.3	1.75	345	4.9	232.3	25.1
$10R^2$	Oct	13.60	20.0	4.3	1.75	345	2.6	12.4	13.2
11	Oct	13.60	22.0	4.0	2.0	414	4.3	19.2	20.0
12	Oct	13.60	17.0	4.1	1.5	414	5.4	31.5	30.1

Steady state was 60 sec. for all tests except ST-1, which was 20 seconds and 10R2 which was 25 seconds.

TABLE 36. TEST RESULTS DIP 1002 (JO 11)

Test no.	Type	Visc. cSt, @ 16°C	Dist. rate m³/hr	Tow speed kts	Slick thk. mm	Belt speed/ tow speed	ORR m³/hr	TE %	TE %
ST-3	Naphtha	6.8	13	2.5	1.9	0.9	4.4	33.3	37.6
6A	Naphtha	6.8	7.2	1.25	2.0	1.9	0.79	11.3	6.9
6B	Naphtha	6.8	6.8	1.25	2.0	1.9	0.86	12.3	7.4
1	DOP	92.0	8.6	1.5	2.1	1.6	0.72	8.5	6.4
2	DOP	92.0	9.7	1.5	2.0	1.4	0.36	3.7	3.2
3	DOP	92.0	7.2	1.25	2.1	1.9	0.36	5.1	3.1
4	DOP	92.0	5.8	1.0	2.0	2.4	1.4	25.6	12.5
5	DOP	92.0	4.3	0.75	2.0	3.2	2.2	52.7	19.1
6	DOP	92.0	2.2	0.5	2.1	4.8	2.4	85.0	20.1
7	DOP	92.0	2.9	0.5	2.1	0	0.36	12.5	3.1
3A	Octanol	12.4	7.2	1.25	2.1	1.7	2.2	30.3	20.5
3B	Octanol	12.4	7.2	1.25	2.1	1.7	2.6	35.6	23.2
4	Octanol	12.4	8.3	1.5	2.1	1.4	2.9	34.8	26.2
5	Octanol	12.4	5.8	1.0	2.0	2.2	2.7	47.6	24.8
ST-1	Octanol	12.4	9.7	1.75	2.0	1.2	4.4	45.0	39.4
ST-2	Octanol	12.4	11.2	2.0	2.0	1.1	2.7	24.8	24.3
3C	Octanol	12.4	7.2	1.25	2.1	1.7	3.0	40.8	25.6
6	Naphtha	6.8	6.8	1.25	2.0	1.9	0.29	4.2	2.7
7	Naphtha	6.8	8.3	1.5	2.1	1.6	2.2	26.9	19.6
8	Naphtha	6.8	9.7	1.75	2.0	1.4	3.6	37.6	31.5
ST-1	Naphtha	6.8	11.2	2.0	2.0	1.2	4.8	43.2	41.5
ST-2	Naphtha	6.8	13	2.25	2.0	1.1	5.0	39.8	42.7

Steady state test time 30 sec for ST-2 and ST-3. For all other tests, it was 60 sec.

Belt speed 2.0 kts for tests 3A, 3B, 3C, ST-1, ST-2, 4 and 5, using Octanol.

Belt speed 2.25 for all other tests.

TABLE 37. TEST RESULTS KAISER OELA III SWISS OIL SKIMMER, SANDPIPER PUMP (JO 11)

Test no.	Visc. cSt @ 16°C	Wave H x L x P m x m x s	ORR m^3/hr	Test fluid %	Water %
2	13.3	calm	14.5	28.9	71.1
5	13.6	0.6 HC	18.8	22.5	77.5
8	6.5	calm	14.2	31.2	68.8
11	6.5	0.6 HC	20.5	25.1	74.9
14	79.2	calm	17.9	39.4	60.6
17	79.2	0.6 HC	20.8	24.0	76.0

Tests 2 and 5 used Octanol
Tests 8 and 11 used Naphtha
Tests 14 and 17 used DOP

TABLE 38. TEST RESULTS RIGID MANTA RAY, 2.5 mm SKIMMER, MARLOW PUMP (JO 11)

Test no.	Visc. cSt @ 16°C	Wave H x L x P m x m x s	Rec. rate m^3/hr	Test fluid %	Water %
1	13.3	calm	15.6	17.6	82.4
1R	13.3	calm	15.5	14.9	85.1
1R^2	13.6	calm	15.6	17.3	82.7
6	13.6	0.6 HC	16.4	11.3	88.7
7	6.5	calm	17.2	27.3	72.7
12	6.5	0.6 HC	17.4	15.9	84.1
13	79.2	calm	13.4	40.1	59.9
18	79.2	0.6 HC	15.2	22.4	77.6
19	79.2	calm	15.7	31.7	68.3
20	79.2	calm	21.6	19.1	80.9
21	79.2	calm	23.3	19.3	80.7
22	79.2	calm	23.2	25.5	74.5
23	79.2	calm	23.4	27.5	72.5

Tests 1 through 6, Octanol used
Tests 7 through 12, Naphtha used
Tests 13 through 23, DOP used

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TABLE 39. TEST RESULTS MARK II-D SKIMMER, OIL MOP PUMP (JO 11)

Test no.	Visc. cSt @ 16°C	Wave H x L x P m x m x s	ORR m^3/hr	Test fluid %	Water %
3	13.3	calm	3.1	78.9	21.1
4	13.6	0.6 HC	4.1	70.0	30.0
9	6.5	calm	2.6	88.6	11.4
10	6.5	0.6 HC	3.5	68.3	31.7
15	79.2	calm	10.0	98.3	1.7
16	79.2	0.6 HC	7.3	72.6	27.4

Tests 3 and 4 used Octanol
Tests 9 and 10 used Naphtha
Tests 15 and 16 used DOP

TABLE 40. OVERALL STATISTICAL DATA (JO 11)

Device	Number of repeat tests	Mean HM recovery rate rate m^3/hr	Variance	Standard deviation $m^3/sx10^{-3}$	95% Confidence level $m^3/sx10^{-3}$	Coefficient of variation %
Seaward Sorbent System	14*	3.96	0.034	0.19	±0.10	17.3
DIP-1002	3	2.59	0.012	0.11	±0.12	15.3
ORS-125	5	4.79	0.021	0.14	±0.12	11.3
Slickbar Mantaray	6	5.22	0.059	0.25	±0.19	16.6
Oil Mop	4*	2.48	0.004	0.06	±0.06	8.7
OELA	5*	4.61	0.016	0.13	±0.11	10.2

*Not repeats of a given test condition--includes all test conditions, since performance appeared to be independent of the test condition.

Throughput efficiency can be analyzed in much the same manner as recovery rate. Optimum efficiencies generally fell within the range of 40-60% with a maximum of 85% when tested with DOP. However, this 85% efficiency occurred at the minimum tow speed of 0.5 kt which is too low for field use consideration.

In the case of the ORS-125, a weir type advancing skimmer, the following test conditions were established:

1. Tow speed = 0.5 to 3.0 kt
2. Air supply to onboard pump = 300 kPa
3. Slick thickness = 4 mm
4. Slick width = 1.52 m
5. Surface condition = calm

Performance was indicated by HM recovery rate, recovery efficiency, and throughput efficiency. A maximum throughput efficiency of 90% occurred when testing with DOP at 0.5 kt and Lube oil at 1.25 kt. When confronted with the low density Naphtha, the device was unable to successfully collect material. The density dependence of the weir-type advancing skimmer was readily observed both visually and quantitatively.

Sorbent System Tests

The throughput efficiencies for the sorbent system, with a fixed tow speed of 2.0 kt, were quantitatively noted as being somewhat independent of test fluid properties. Also, the device when subjected to "random" wave surface conditions, maintained a high throughput efficiency of between 60 and 80%. As in the results of the oleophilic rope, the effects of natural hydrodynamic forces which tended to cause high density materials to become entrained were reduced. The absorption rate of the sorbent material for various test fluids played an important role in effective spill removal. The sorbent system tested utilized polyurethane open-celled foam which adsorbed material rapidly and was easily regenerated. Recovery efficiency was maximized at 80% in the no wave condition with Naphtha.

Recovery rate was optimized with octanol and was even higher with the 0.6 m harbor chop. However, the experimental determination of recovery rate was not as accurate as for throughput and recovery efficiencies.

Summary

The relationships in Table 41 are based on the evaluation of data available in the appendices of this report and serve to summarize the test program.

TABLE 41. PROPERTIES AFFECTING PERFORMANCE (JO 11)

Test Device	Physical properties that affect performance
Boom	density, interfacial tension (I.F.T.)
Stationary Skimmer	density, I.F.T., viscosity
Advancing Skimmer	density, I.F.T., viscosity
Sorbent System	depends on compatibility with sorbent cubes; otherwise independent

JOB ORDER NO. 12 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	19 March - 15 April 1975
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817 201-321-6600
Device	Trailer-mounted carbon adsorption system

Description of Program

OHMSETT personnel responded to a spill of kepone near The Plains, Virginia. A trailer-mounted carbon adsorption system developed for EPA was used to remove kepone from a small pond and stream.

JOB ORDER NO. 13 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	6 June 1975
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817 201-321-6600
Device	Oil Harvester Skimmer Pennsylvania State University Department of Mechanical Engineering University Park, PA 16802 814-865-6852

Description of Program

A one-day test program was conducted to evaluate a prototype oil skimmer developed by a group from Pennsylvania State University. This skimmer used a paddle wheel to draw surface oil toward a weir box located at the apex of a vee formed by two boom arms.

JOB ORDER NO. 14 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 2-12 September 1975

Customer
Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Device
Reusable Sorbent Cube Skimmer
Seaward International, Inc.
6269 Leesburg Pike
Falls Church, VA 22044 703-534-3500

Reports

Dorrler, J.S. and S.H. Shaw. A Distributed Reusable Sorbent Oil Recovery System. In: Proceedings of the 1977 Oil Spill Conference, American Petroleum Institute, New Orleans, Louisiana, 1977. pp. 247-250 (Ref. 18).

Shaw, S.H., R.P. Bishop, and R.S. Powers. Development of a Sorbent Distribution and Recovery System. EPA-600/7-27-217, U.S. Environmental Protection Agency, 1978 (Ref. 45).

Description of Program

A prototype reusable-sorbent oil recovery system intended for harbors, rivers, and the vicinity of piers and pilings was evaluated by the U.S. EPA. The device, as designed and fabricated by Seaward International, Inc. consisted of a pneumatic sorbent broadcasting unit, sorbent harvesting belt (catamaran-mounted), and a sorbent regenerator. Consideration was given to such performance-related variables as sorbent-oil contact time, contact area, tow speed, broadcast rate, oil thickness, surface conditions, and oil type. Sorbent samples taken at various points in the system aided in monitoring the condition of the open-cell polyurethane sorbent cubes. A 16 mm movie film entitled, "Development of Sorbent Distribution and Recovery System," is available through the Oil and Hazardous Materials Spill Branch, U.S. Environmental Protection Agency, Edison, New Jersey 08817.

Conclusions

Of necessity, the OHMSETT testing of the prototype sorbent oil recovery system was limited in its extent. Tests were limited to a small number of speeds, wave conditions, and slick thicknesses and, because of physical limitations, testing was not done in a continuous mode. Still, the system demonstrated that the concept is sound and that the prototype equipment is a useful tool in the cleanup of spilled oils and selected floating hazardous substances, at a minimum, for the range of conditions under which it was tested. These conditions were; relative velocities of up to 5 knots, waves up to 0.3 m height, and slick thicknesses from 0.24 mm to 0.84 mm.

Under the best conditions the system was able to collect virtually all of the oil encountered. Better than 40 percent of the oil encountered was collected even under the most adverse conditions of high speed and waves.

In the best test case, oil was collected at a rate of 10.5 m^3/hr, from a 0.5 mm slick at a sweep speed of 2.5 knots with a sorbent distribution rate of 17.4 m^3/hr.

The recovery system is highly mobile, being transportable in only two pickup trucks. With the exception of the foam regenerator, all system elements can be transported manually over rough terrain.

Sorbent losses due to wind effects with wind velocities up to 15 knots are negligible. More significant foam losses occur due to waves washing over the containment boom. During the test program, the maximum losses occurred at 5-knot sweep speeds in 0.3 m breaking waves. These losses were less than 2%.

Regenerated foam densities were significantly higher than were predicted from prior laboratory tests. The design regenerated foam density was 140 kg/m^3 using a roller squeeze force of 7 N/mm. During testing, the regenerated foam density averaged 160 kg/m^3 using an average squeeze force of 16 N/mm. This probably resulted from oil clinging to the outside of the foam during squeezing and then being reabsorbed into foam when the squeeze force was removed. During testing, the oil concentration varied from 38% to 79%. The recovered liquid was not highly emulsified and gravity separation of the oil and water was rapid.

Complete removal of all oil, or "sheen polishing," is not possible using recycled foam in this system because of oil remaining in the foam cubes after regeneration.

System throughput efficiency could be improved by operating with a sorbent logjam in front of the harvester. This would increase contact time which, as the test results indicate, would increase throughput efficiency. Operating with a logjam was not done during the test program, in order to reduce the number of test variables.

It is recommended that the system be operated on a variety of actual oil spills to gain additional performance information under more realistic conditions.

It is recommended that the system be operated in a continuous mode in order to prove its capabilities in this mode since physical limitations prevented testing in this mode at OHMSETT.

It is recommended that in order to improve the tracking of the regenerator upper squeeze belt and to eliminate the slippage between the belt and the drive roller, that standard drive roller lagging be applied in narrow strips with oil resistant adhesive and should be applied in a helical or chevron pattern from either end of the roller.

JOB ORDER NO. 15 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	3-14 November 1975
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817 201-321-6600

Devices
High Current Boom
Ultrasystems, Inc.
2400 Michelson Drive
Irvine, CA 92715 714-752-7500

Report Folsom, B.A. Development of a High Current Oil Boom/Skimmer, EPA-600/2-80-140. U.S. Environmental Protection Agency, Cincinnati, Ohio 45268, 1980 (Ref. 20).

Folsom, B.A. and C. Johnson. Development of a High Current Streamlined Boom/Skimmer for Inland Waterways. In: Proceedings of the 1977 Oil Spill Conference, American Petroleum Institute, New Orleans, Louisiana, 1977 (Ref. 21).

Description of Program

In 1975 and 1976, a slightly submerged slotted hydrofoil with an attached sump was evaluated by the EPA for use as a high current skimmer. The device was designed and fabricated by Ultrasystems, Inc. and tested as an integrated system (including a stability and floatation control mechanism). Both lubricating stock and No. 2 fuel oil in selected slick thicknesses were directed to the device under tow. Oil recovery rate, recovery efficiency, and throughput efficiency were then determined and related to the controlled independent variables. A report, EPA-600/2-80-140 is available through NTIS.

Conclusions

The streamlined oil boom was tested at two velocities, 3 and 6 knots, with sump preloads ranging from 0.02 to 0.38 m^3 and with oil slick thicknesses ranging from 1 to 3 millimeters. The oil was recycled 500 centistoke lube oil stock. It had previously been used to test other pollution equipment and then reclaimed for subsequent use. Because of this previous use, the viscosity was reduced to about 150 centistokes and its appearance was much like brown muddy water. Representative oil samples were taken from the oil supply tank daily and whenever additional oil was added.

Holding Tests - Results

Although these were the first quantitative holding tests to be conducted on the complete oil boom, some qualitative tests were conducted with oil in the sump. These qualitative tests revealed oil head waves similar to those observed on the retained oil upstream of conventional oil booms. Consequently, the usual headwave failure problems were anticipated. However, the holding tests at OHMSETT proved that large amounts of oil could be held in the sump without substantial losses.

The basic streamlined oil boom design performed well at 3 knots. The 1.5 m working section could hold almost 0.28 m^3 in the primary sump before losing 15 percent of the volume deposited. At 6 knots, however, the streamlined oil boom lost approximately 80 to 85 percent of the oil deposited. About half of the amount retained had sloshed into the secondary sump on startup and thus did not have opportunity to be lost so the actual efficiency was only about 7 to 10 percent. The problem was that at 6 knots the hydraulic jump increased in intensity and moved downstream with a large portion of the roller in the oil slick.

Installing the array of surface piercing rods improved performance, but 40 to 50 percent of the oil deposited was still lost. The turbulence generated by the rods was of much smaller scale than that generated by the hydraulic jump (0.6 mm versus a 10 mm typical eddy size) allowing the energy dissipation to occur in a shorter distance.

The porous sump bottom reduced losses even further. It increased the effective depth in the sump, decreased the average sump velocity, and reduced the turbulence level and head wave failure. The streamlined oil boom with the array of surface piercing rods and porous bottom held almost 0.19 m^3 with a loss of only 1.4 percent at 6 knots. Since 0.19 m^3 was the largest volume tested and losses were quite small, the sump capacity with these two modifications was probably substantially larger.

The 6 knot data from the percentage of oil retained in the sump versus the amount of oil deposited in the sump show the rise in performance associated with the sump modifications. The performance at 6 knots with modification is on par with the excellent 3 knot performance without modifications. The 3 knot data shows little variation as the oil volume is increased from 0.02 to 0.28 m^3. Since losses do not rise significantly as oil volumes tested increase, no "sump capacity" can be defined. It should be noted, however, that the 0.24 m^3 retained in the sump in the 0.28 m^3 preload test at 6 knots represents an oil slick about 5 mm deep over the entire sump area with the upstream end of the slick in the array of rods.

Bow Tests - Results

The 3 knot tests were conducted with no modifications to the basic sump design and demonstrate excellent performance. Two types of throughput efficiency have been calculated. The total throughput efficiency is the ratio of volume of oil retained in the sump to the volume distributed and is a measure of the test results. A corrected throughput efficiency has been calculated to separate the losses at the bow and hydraulic jump from the losses associated with the oil slick in the sump. The corrected throughput efficiency is an estimate of the amount of oil forming a slick after passing over the sump inlet and through the hydraulic jump and was calculated by applying the results of the holding tests.

It was expected that an increase in the slick thickness would increase throughput efficiency. It was reasoned that the viscous oil would decrease the sump turbulence level. However, throughput efficiency actually decreased with increasing slick thickness. It appears that a thicker oil layer causes a larger amount of oil to be mixed in the turbulence and as a result a larger amount of oil to be lost.

The 6 knot data show the effects of the sump modifications. Without modifications, the hydraulic jump extended nearly the full length of the primary sump with large-scale turbulence. Throughput efficiency was essentially zero with only patches of oil remaining in the sump after the run. Addition of the array of surface piercing rods increased efficiency to 42 percent, and subsequent addition of the porous bottom increased efficiency even further to 60 percent.

Collection Tests

As mentioned earlier, the corrected throughput efficiency is the percentage of oil distributed upstream of the boom which was retained in the sump. This was calculated by subtracting the preload volume from the total volume retained and dividing by the volume distributed. The two 3 knot collection tests were conducted before the system reaction time problem was understood and consequently no preload was used and collection efficiency could not be measured. Even though the recovery pumps were operated during the run, no oil passed over the weir until near the end of the run. Thus, these tests were much like bow tests and produced throughput efficiencies nearly the same as the 3 knot bow tests.

All of the 6 knot collection tests were conducted on the streamlined oil boom with the array of surface piercing rods and the porous sump bottom installed and with oil slicks about 1 mm thick. The four tests with numerical results gave throughput efficiencies ranging from 40 to 72 percent.

Corrected throughput efficiency decreased as the amount of flow entering the sump increased. Larger flow rates increase the velocity in the primary sump resulting in higher losses. Since highest efficiencies were obtained for those runs skimming off a thin 19 to 25 mm layer, proper design of a floatation system is critical.

The relationship between corrected throughput efficiency and sump preload for the 6 knot tests shows essentially no effect of preload up to 0.15 m^3 (considering the data scatter at 0.08 to 0.15 m^3 preload).

Sump preload does have an effect on the flow over the weir and collection efficiency. For a fixed weir flowrate, the amount of oil passing over the weir is a function of slick thickness. It appears that collection efficiencies higher than 50 percent can easily be obtained if sump oil volume is maintained at 0.11 m^3 or more. As previously discussed, an equilibrium sump oil volume is approached asymtotically as time progresses. This equilibrium volume is a function of the rate of oil distribution and flowrate over the weir (assuming the hydrodynamic parameters--freeboard, velocity, etc.--remains constant). Straight lines for the time histories for the 6 knot collection tests were drawn between the beginning and ending points since no intermediate data were available. For weir flowrate of 16.8 to 19.1 m^3/hr, equilibrium sump volume appears to be about 0.1 m^3 (average of the three final volumes). As expected, increasing the weir flowrate to 35 m^3/hr decreases the equilibrium sump volume to something less than 0.08 m^3.

JOB ORDER NO. 16 - U.S. NAVY

Dates 17-21 November 1975

Customer Naval Facilities Engineering Command
200 Stovall Street
Alexandria, VA 22332 202-546-6700

Device

Multi-frequency Microwave Transmitter/Receiver
Naval Research Laboratory (NRL)
U.S. Navy
Washington, DC 20375 202-767-3683

Report

Hollinger, J.P. and J.E. Kenney. Evaluation of a Passive Microwave Technique for Measurement of Oil Film Thickness in a Test Tank Environment. NRL Report 3308, U.S. Naval Research Laboratory, Washington, DC, 1976 (Ref. 26).

Description of Program

A multi-frequency passive microwave technique for the measurement of oil film thickness was evaluated in calm and harbor chop wave conditions. The device was mounted on the north side of the main bridge which traveled the length of the test tank at various tow speeds distributing known thicknesses of oil. NRL memorandum Report 3308 describes the results and is available from the Naval Research Laboratory, Washington, DC 20375.

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TABLE 42. SUMMARY OF OHMSETT OIL TESTS HIGH CURRENT BOOM (JO 15)

Test no.	Type of test	Modifications to basic design	Tow velocity kts	Sump preload $\times 10^{-2}$ m^3	Oil Distribution Layer thk. mm	Layer length m	Volume $\times 10^{-2}$ m^3	ORR m^3/hr
1	Bow	none	3	none	0.82	15.2	1.8	---
2	Holding	none	3	1.9	---	---	---	---
3	Bow	none	3	none	1.59	15.2	3.7	---
4	Holding	none	3	9.4	---	---	---	---
5	Bow	none	3	none	3.3	22.9	7.7	---
6	Holding	none	3	28.2	---	---	---	---
7	Collection	none	3	none	1.11	61	10.3	17.1
8	Collection	none	3	none	1.03	61	9.1	13.2
9	Bow	none	6	none	0.82	30.5	3.8	---
10	Holding	none	6	18.9	---	---	---	---
11	Holding	none	6	37.7	---	---	---	---
12	Holding	*	6	18.9	---	---	---	---
13	Holding	*	6	20.8	---	---	---	---
14	Bow	*	6	none	0.84	30.5	3.9	---
15	Holding	**	6	18.8	---	---	---	---
16	Collection	**	6	15.1	0.99	61	9.1	---
17	Collection	**	6	15.1	1.10	61	10	19.1
18	Collection	**	6	7.5	1.10	61	10.3	16.9
19	Collection	**	6	7.5	1.10	61	9.8	16.9
20	Collection	**	6	15.1	1.10	61	10.4	34.9
21	Bow	**	6	---	1.20	61	10.9	---

*Surface piercing roughness.
**Porous sump bottom and surface piercing roughness.

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TABLE 43. SUMMARY OF OHMSETT HOLDING TESTS RESULTS HIGH CURRENT BOOM (JO 15)

Test no.	Modification to basic design	Velocity knots	Preload volume in sump $\times 10^{-2} m^3$	Final volume in primary sump $\times 10^{-2} m^3$	Final volume in secondary sump $\times 10^{-2} m^3$	Percent retained	Percent lost
2	none	3	1.9	1.7	---	90.8	9.2
4	none	3	9.4	9.8	---	100+	---
6	none	3	28.2	24	---	84.8	15.2
10	none	6	18.9	2	1.2@	16.7	83.3
11	none	6	37.7	4.2	1.8@	15.8	84.2
12	*	6	18.9	8.1	2.7	57.1	42.9
13	*	6	20.8	5.9	4.4	51.0	48.9
15	**	6	18.8	13.2	5.2	98.6	1.4

*Surface piercing roughness.
**Surface piercing roughness and porous bottom.
@Determined from measurement of oil layer in secondary sump.

TABLE 44. SUMMARY OF OHMSETT BOW TEST RESULTS, HIGH CURRENT BOOM (JO 15)

Test no.	Modification to basic design	Velocity knots	Slick thk. mm	Length m	Volume $\times 10^{-2}\ m^3$	Flow rate m^3/hr	Vol. oil retained $\times 10^{-3}\ m^3$	Total thruput eff. %	Corrected thruput eff. %
1	none	3	0.8	15.2	1.8	6.8	1.6	86.5	95.0
3	none	3	1.6	15.2	3.7	13.3	2.3	71.2	78.7
5	none	3	3.3	15.2	7.7	27.9	4.7	60.6	67.7
9	none	6	0.8	30.5	3.8	13.6	0	0	0
14	*	6	0.8	30.5	3.9	14	1.6	41.6	75.7
21	**	6	1.2	61	10.9	19.8	6.5	59.6	60.0

*Surface piercing roughness.
**Surface piercing roughness and porous bottom sump.

SECTION 6

TESTS PERFORMED IN 1976

JOB ORDER NO. 17 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 15-25 November 1976

Customer
Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Device
OHMSETT Wave Generation System
Resistance Wave Probe
Steven Institute of Technology
Davidson Laboratory
Castle Point
Hoboken, NJ 07030 201-420-5100

Report In-house report only.

Description of Program

This program used a resistance wire wave measuring probe to measure wave heights in the OHMSETT tank available for test program use.

JOB ORDER NO. 18 - U.S. NAVY (SEE JOB ORDER NO. 19 ALSO)

Dates 17 May - 4 June 1976

Customer
Civil Engineering Laboratory
U.S. Naval Construction Battalion Center
Port Hueneme, CA 93043 805-982-5435

Devices
Komara Miniskimmer
British Petroleum Co., Ltd.
BP Research Center
Chertsey Road
Sudbury-on-Thames
Middlesex, England TW 16 7LN 85533 EXTN

Lockheed Cleansweep Model 150F Skimmer
Lockheed Missiles & Space Co.
P.O. Box 504, Bldg. 570
Sunnyvale, CA 94086 408-988-0906

Sea Hawk Skimmer
Pollution Abatement Associates
5643 Paradise Drive, Suite 7
Corte Madera, CA 94925 415-924-8587

Expandi-Boom
Whittaker Corporation
5845 River Road
New Orleans, LA 70183 504-733-7050

5159 Baltimore Drive
La Mesa, CA 92041 714-469-0171

2600 S. Gessner, Suite 311
Houston, TX 77063 713-784-0650

Reports Widawsky, A. Performance Tests of Three Skimmers and One Boom at OHMSETT. TM-60P-76-11, U.S. Naval Civil Engineering Laboratory, 1976 (Ref. 55).

Wilson, J.E. Surface Enhancement--Bringing It All Together. In: Proceedings of the 1977 Oil Spill Conference, American Petroleum Institute, New Orleans, Louisiana, 1977 (Ref. 56).

Description of Program

Over the two year period 1975-1976, the Naval Facilities Engineering Command (NAVFAC) sponsored a test program of various booms and skimmers. The program was conducted by the Civil Engineering Laboratory (CEL) and included evaluations of the JBF-DIP 3001, JBF-DIP 1001, Komara Miniskimmer, Lockheed Cleansweep Model 150F, Whittaker Expandi-Boom, Bennett Sea Hawk, Bennett Boom, and Southwestern Research Institute Boom. Skimmers were tested both in the advancing and stationary modes while booms were tested in the containment configuration while being towed in following and head seas. As a result of this program, specific recommendations were presented to NAVFAC for employment of these devices and statistical information on the repeatability of test results was derived. A technical memorandum (TM 60P-76-11) is available from the Civil Engineering Laboratory, Naval Construction Battalion Center, Port Hueneme, CA 93043.

Conclusions

Komara Miniskimmer

In the stationary mode, with hosing, the oil collection rate of the Komara Miniskimmer was independent of disk speed. The collection efficiency, however, decreased as disk speed increased. Waves with a nominal wave height of 0.15 m slightly increased the oil collection rate; however, they did decrease the collection efficiency.

In the advancing mode, the oil collection rate and throughput efficiency of the Komara Miniskimmer increased as the disk speed increased. The collection efficiency, however, decreased as the disk speed increased. Waves with a nominal wave height of 0.15 m caused significant decreases in all three performance parameters.

In the advancing mode, there was one value of tow speed of the Komara Miniskimmer, at constant disk speed, which resulted in a maximum value of the oil collection rate. Collection and throughput efficiency, however, decreased as tow speed increased.

In the advancing mode, the oil collection rate of the Komara Miniskimmer increased as the oil slick thickness increased. The increase, in the oil collection rate, however, was far less than the increase in the volume of additional oil encountered. Consequently, the throughput efficiency decreased as the oil slick thickness increased. The change in collection efficiency was small and inconclusive.

Lockheed Clean Sweep, Model 150F

In the stationary mode with hosing, there was one disk speed of the Lockheed Clean Sweep, Model 150F, which yielded maximum values of the oil collection rate and the collection efficiency. Waves with a nominal wave height of 0.15 m decreased both the oil collection rate and the collection efficiency.

In the stationary mode, with hosing, better performance of the Lockheed Clean Sweep, Model 150F, was obtained by hosing the oil directly into the front of the skimmer than by hosing the oil from the back to the front of the skimmer in order to form a pool of oil which was then skimmed by the rotating disks.

In the advancing mode, there was one disk speed of the Lockheed Clean Sweep, Model 150F, which yielded maximum values of the oil collection rate and the throughput efficiency. Collection efficiency, however, decreased as disk speed increased. Waves with a nominal wave height of 0.15 m caused a significant decrease in all three performance parameters.

In the advancing mode, the oil collection rate and the throughput efficiency of the Lockheed Clean Sweep, Model 150F, decreased as the tow speed increased. The collection efficiency was not significantly affected by tow speed.

In the advancing mode, the oil collection rate of the Lockheed Clean Sweep, Model 150F, increased as the oil slick thickness increased. The increase in the oil collection rate, however, was less than the increase in the volume of additional oil encountered. Consequently, the throughput efficiency decreased as the oil slick thickness increased. The collection efficiency remained essentially constant as the oil slick thickness increased.

Sea Hawk

In both the stationary and advancing modes, unsuccessful attempts to determine optimum values of ballasting and position of the weir pipe precluded obtaining consistent test results.

Comparison of Skimmers

The test results reported have been compared with each other and with the results of the JBF DIP 1001, obtained in previous tests.

In the stationary mode, the JBF DIP 1001 had the highest maximum oil collection rate, 2.5 m^3/hr. The Komara Miniskimmer, Lockheed Clean Sweep, Model 150F, and the Sea Hawk had maximum oil collection rates of 0.6, 0.34, and 0.99 m^3/hr respectively.

Assuming that the collection well of the JBF DIP 1001 is pumped in accordance with the operator's manual, and assuming that collection efficiency tests on the JBF DIP 3001, conducted previously by CEL, are also valid for the JBF DIP 1001, the collection efficiency of the JBF DIP 1001 in the stationary mode is taken to be in excess of 99 percent. Of the other three skimmers, the collection efficiency of the Lockheed Clean Sweep, Model 150F, 93.3 percent, corresponding to its maximum oil collection rate, was more than twice as high as the collection efficiencies of the Komara Miniskimmer, 43.1 percent, and of the Sea Hawk, 41.3 percent, at their maximum oil collection rates.

In the advancing mode, the Komara Miniskimmer had the highest value of the oil collection rate, 1.3 m^3/hr (with a nominal oil slick thickness of 2.4 mm, and a tow speed of 0.47 knot). The Lockheed Clean Sweep, Model 150F, Sea Hawk, and JBF DIP 1001 skimmers obtained maximum oil collection rates of 0.32, 0.79, and 0.61 m^3/hr, respectively.

The collection efficiency of the JBF DIP 1001 in the advancing mode is again assumed to be over 99 percent. Of the other three skimmers, the collection efficiency, corresponding to the maximum oil collection rate, of the Lockheed Clean Sweep, Model 150F, 85.8 percent, was the highest. The collection efficiencies of the Komara Miniskimmer and the Sea Hawk were 33.4 and 51.4 percent, respectively.

The highest throughput efficiency in the advancing mode, 50.6 percent, corresponding to the maximum oil collection rate, was obtained by the Komara Miniskimmer. The throughput efficiencies of the JBF DIP 1001, Lockheed Clean Sweep, Model 150F, and the Sea Hawk were 42.4, 30.4, and 33.6 percent, respectively.

Whittaker-Expandi Boom

In no waves, the Whittaker Expandi-Boom started to lose oil at about 0.9 knot. In the presence of waves with nominal wave heights of 0.15 to 0.3 m, the boom started to lose oil at less than 0.49 knot.

The oil loss rates of the Whittaker Expandi-Boom in waves with nominal wave heights of 0.15 and 0.3 m, in the head seas condition, and in waves with a nominal wave height of 0.45 m, in the following seas conditions, were nearly the same.

In no waves, the performance of the Whittaker Expandi-Boom was essentially the same as that of the SwRI prototype boom with a frontal screen, which was tested previously. Compared to the Bennett Class III Navy boom, also tested previously, the

TABLE 45. PERFORMANCE OF THE KOMARA MINISKIMMER, STATIONARY MODE (JO 18)

Test no.	Test oil cSt @ 38°C	Nominal wave height m	Nominal oil slick thk. mm	Hosing	Disk speed rpm	ORR $\times 10^{-2} m^3/hr$	RE %
K -1	20	0	1.5	No	52.3	13.2	38.0
K -2	20	0	2.0	No	92.9	16.6	43.2
K -3	10	0	1.0	No	90.1	3.9	17.0
K -4	10	0	1.1	No	59.9	13.9	57.5
K -5	10	0	1.1	No	110	3.2	9.2
K -6	10	0	2.2	No	125	1.8	8.4
K -7	10	0	5.7	Yes	125	27.7	33.0
K -8	10	0	4.5	Yes	106	19.8	39.2
K -9	10	0	4.7	Yes	89.8	22	62.3
K-10	10	0	5.3	Yes	58.9	25	71.9
K-11	10	0	5.0	Yes	136	14.8	13.6
K-12	10	0	6.7	Yes	138	29.5	28.3
K-13	10	0	23	Yes	139	59	43.1
K-14	10	0	10	Yes	137	50.9	30.9
K-15	10	0	4.1	Yes	136	55	37.1
K-16	10	0	10	Yes	138	55	36.1
K-17	10	0	10	Yes	137	50	31.1
K-18	10	0.15	10	Yes	137	30.7	12.3
K-19	10	0.15	5.8	Yes	111	23.4	13.2
K-20	10	0.15	8.1	Yes	92.8	36.6	22.8

(Continued)

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TABLE 45. (Continued)

Test no.	Test oil cSt @ 38°C	Nominal wave height m	Nominal oil slick thk. mm	Hosing	Disk speed rpm	ORR $\times 10^{-2} m^3/hr$	RE %
K-21	10	0.15	6.8	Yes	72.4	30	36.2
K-22	10	0.15	4.5	Yes	131	30.9	10.9
K-23	10	0.15	16	Yes	108	30	18.7

Notes:

1. The Komara miniskimmer was placed in a circular boomed area. The enclosed area was 97.5 m^2, the radius was 5.6 m.

2. The discharge ORR of the hose was 13.6 m^3/hr, with an exit velocity of 29.9 m/s.

3. Approximately 9.85 m^3 of oil were applied to the water surface for all tests except K-11 and K-12; 4.9 $\times 10^{-2} m^3$ were applied in Test K-11; 19.7 m^3 were applied in Test K-12.

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TABLE 46. PERFORMANCE OF THE LOCKHEED CLEAN SWEEP, MODEL 150F, STATIONARY MODE (JO 18)

Test no.	Nominal wave height m	Skimmer config.*	Float position*	Disk speed rpm	ORR x$10^{-2}m^3$/hr	RE %
L -1	0	Backward	Low	19.2	8.4	55.1
L -2	0	Backward	Low	14.2	1.2	70.8
L -3	0	Backward	Low	10.0	13.9	78.6
L -4	0	Backward	Low	5.2	5.9	67.8
L -5	0	Backward	Low	25.2	7.7	41.1
L -6	0	Backward	Low	9.8	14.3	81.5
L -7	0	Backward	Low	10.1	15.2	92.9
L -8	0	Backward	High	10.0	16.1	84.0
L -9	0	Backward	High	10.5	17.5	84.5
L-10	0.15	Backward	High	10.4	6.4	60.3
L-11	0.15	Backward	High	23.1	2.7	23.0
L-12	0.15	Backward	High	15.8	4.3	45.1
L-13	0.15	Backward	High	4.9	5.0	80.3
L-31	0	Forward	High	14.6	21.6	82.4
L-32	0	Forward	High	26.0	7.7	37.2
L-33	0	Forward	High	20.1	3.4	93.3

Notes:

1. In the backward configuration, the rotating disks were faced away from the oncoming oil slick. The oil was hosed around the skimmer, collecting in front of the skimmer, where it was skimmed by the rotating disks. In the forward configuration, the rotating disks faced the oncoming oil slick.

2. The high position of the floats was approximately one inch higher than the low position. Thus, in the high position, the rotating disks were lower in the water.

3. Test oil was 10 cSt @ 38°C.

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TABLE 46. (Continued)

4. Hosing was used in all the tests. The maximum discharge rate of the hose was 13.6 m^3/hr with a maximum exit velocity of 29.9 m/s.

5. For tests 1-13, the skimmer was placed within a boom that was approximately catenary in shape. Before hosing started, the nominal oil slick thickness was 2 mm.

6. For tests 31-33, the skimmer was placed at the apex of a boom that was approximately catenary in shape. When skimming started, the nominal oil slick thickness was increased to approxiamtely 4 mm by hosing.

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TABLE 47. PERFORMANCE OF THE SEA HAWK SKIMMER, STATIONARY MODE (JO 18)

Test no.	Nom. wave ht. m	Dist. of weir lip* mm	Dist. of weir pipe** mm	Wt. add. to skim. kg	Pump set.	Hose time min	Pump time min	Pump dis. rate x10^{-2}	ORR m^3/hr	RE %
S -1	0			0	max.	12.00	12.00	34	25	74.3
S -2	0			0	2/3 max.	8.53	8.53	61	24	39.3
S -3	0		63.5	16	1/3 max.	3.68	3.68	232	75	32.2
S -4	0		63.5	16	max.	3.92	3.92	254	74	28.9
S -5	0		63.5	16	max.	4.28	4.28	201	79	39.3
S -6	0		63.5	16	max.	3.42	3.42	238	98	41.3
S -7	0	31.8	6.4	0	max.	4.03	1.37	241	15	18.6
S -8	0	19	12.7	0	max.	4.90	3.63	76	30	54.1
S -9	0	6.4	12.7	0	max.	4.84[2]	0.85[2]	804	30	20.9
S-10	0.15	-19	19	0	max.	2.75[2]	5.50[2]	243	97	20.0
S-27	0.15	0	6.4	0	max.	1.58	6.50	243	58	5.8
S-28	0.15	0	6.4	0	max.	1.92	7.00	236	129	15.0
S-29	0.15	0	6.4	0	2/3 max.	1.93	14.50	132	143	14.5
S-30	0.15	0	6.4	0	1/3 max.	1.73	12.00	129	153	17.0
S-31	0.15	0	6.4	0	min.	2.52	12.00	86	95	23.4

Notes:

1. During Tests S-1 to S-6, hosing and pumping were done simultaneously.
2. Pumping started 15 seconds before hosing ended.
3. Test oil was 20 cSt @ 38°C.
4. Two fire hoses were used. The maximum discharge rate of each hose was 13.6 m^3/hr with a maximum discharge velocity of 29.9 m/s.
5. The skimmer was placed at the apex of a boom that was approximately catenary in shape. When skimming started, the nominal oil slick thickness was increased to approximately 68 mm by hosing.

*above water, **below water

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TABLE 48. STATISTICAL SUMMARY OF THE PERFORMANCE OF THE SEA HAWK SKIMMER, STATIONARY MODE (JO 18)

Test cond.	No. of data points	Avg. ORR $\times 10^{-2}$ m^3/hr	Stan. dev. ORR $\times 10^{-2}$ m^3/hr	Avg. RE %	Stan. dev. RE %
No added weights, no waves	5	0.25	0.06	41.4	23.4
Added weights, no waves	4	0.81	0.12	35.4	5.8
No added weights, nominal wave height of 0.5 ft	6	1.1	0.36	16.0	6.0

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TABLE 49. PERFORMANCE OF THE KOMARA MINISKIMMER, ADVANCING MODE (JO 18)

Test no.	Nominal wave height m	Nominal oil slick thk. mm	Tow speed kts	Disk speed rpm	ORR x10^{-2} m^3/hr	RE %	TE %
K-24	0	1.92	0.494	109	1.1	32.5	44.1
K-25	0	2.51	0.494	125	1.3	33.4	50.6
K-26	0	2.46	0.494	58	0.74	63.0	28.8
K-27	0	2.26	0.494	90.6	0.84	43.5	32.7
K-28	0	2.52	0.741	136	1.3	27.7	33.8
K-29	0	2.83	0.988	133	0.89	19.7	17.4
K-30	Aborted						
K-31	0	4.87	0.494	133	1.3	30.1	24.1
K-32	0	2.69	0.494	135	1.2	47.5	45.1
K-33	0	3.54	0.494	135	1.5	35.3	38.6
K-34	0	2.33	0.494	134	1.0	25.8	39.6
K-35	0	2.29	0.494	133	1.0	28.2	40.9
K-36	0.15	2.37	0.494	134	0.63	12.6	24.7
K-37	0	1.36	0.494	133	0.83	25.7	57.2
K-38	0.15	2.72	0.494	113	0.28	14.1	10.8
K-39	0.15	3.15	0.494	84.6	0.39	16.0	15.2
K-40	0.15	2.43	0.494	64.7	0.3	19.0	11.8

Notes:

1. Except where noted, oil collection rates are adjusted for a nominal slick thickness of 2.4 mm.
2. Oil collection rate not adjusted.
3. Test oil was 10 cSt oil @ 38°C.

TABLE 50. PERFORMANCE OF THE LOCKHEED CLEAN SWEEP, MODEL 150F, ADVANCING MODE (JO 18)

Test no.	Nominal wave height m	Nominal oil slick thk. mm	Tow speed kts	Disk speed rpm	ORR $\times 10^{-2}$ m^3/hr	RE %	TE %
L-14	0	2.50	0.494	24.8	12.0	53.7	11.2
L-15	0	2.65	0.494	15.1	32.0	85.8	30.4
L-16	0	2.55	0.494	10.3	30.0	93.6	28.0
L-17	0	2.50	0.494	4.87	7.0	99.2	6.7
L-18	0	2.46	0.741	9.9	27.0	93.6	17.0
L-19	0	2.29	0.988	9.9	26.0	91.4	12.0
L-20	0	4.49	0.494	15.11	33.0	88.0	16.6
L-21	0	3.36	0.494	15.31	27.0	82.7	18.0
L-22	0	2.86	0.494	15.2	22.0	83.7	20.6
L-23	0	2.45	0.494	14.98	26.0	84.8	24.1
L-24	0	2.55	0.494	15.28	28.0	86.9	26.5
L-25	0.15	2.24	0.494	14.8	5.0	34.6	4.7
L-26	0.15	2.35	0.494	21.96	2.7	15.5	2.6
L-27	0.15	2.87	0.494	9.94	3.6	36.7	3.5
L-28	0.15	2.35	0.494	14.4	2.5	24.4	2.3
L-29	0.15	2.24	0.494	14.27	2.5	18.2	2.4
L-30	0.15	2.24	0.494	14.25	2.5	16.8	2.4

Notes:

1. Except where noted, oil collection rates are adjusted for a nominal slick thickness of 2.4 mm.

2. Oil collection rate not adjusted.

3. Test oil was 10 cSt oil @ 38°C.

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TABLE 51. PERFORMANCE OF THE SEA HAWK SKIMMER, ADVANCING MODE (JO 18)

Test no.	Nom. wave ht. m	Nom. slick thk. mm	Dist. of weir lip* mm	Dist. of weir pipe** mm	Test time min	Tow speed kts	ORR[1] $\times 10^{-2} m^3/hr$	RE %	TE %
S-11	Aborted								
S-12	0	2.76	-6	6	5.0	0.494	47	48.7	39.4
S-13	0	2.38	-6	6	4.0	0.741	40	28.3	22.2
S-14	0	2.44	-6	6	3.5	0.988	79	51.4	33.6
S-15	0	4.98	-6	6	5.0	0.494	57	26.0	23.3
S-16	0	2.40	-6	6	5.0	0.494	20	9.6	17.2
S-17	0	2.30	-19	19	5.0	0.494	23	18.7	19.8
S-18	0	7.28	-19	19	5.0	0.494	38	19.4	10.5
S-19	0	2.40	-19	19	5.0	0.494	11	12.0	9.5
S-20	0	3.57	-38	28.7	4.0	0.494	43	9.1	24.5
S-21	0	2.25	-38	28.7	3.0	0.741	17	3.4	9.6
S-22[3]	0	2.21	-35	28.7	2.5	0.988	40		17.1
S-23	0.15	2.21	0	6	2.5	0.988	31	12.8	13.1
S-24	0.15	2.33	0	6	5.0	0.741	6.4	2.7	3.6
S-25	0.15	2.24	0	6	5.75	0.494	58.6	21.6	49.6
S-26	0.15	2.33	0	6	5.0	0.741	39.5	19.0	22.2

Notes:

1. Except where noted, oil recovery rates are adjusted for an oil slick thickness of 2.4 mm.
2. Oil recovery rate not adjusted.
3. All the oil collected on this run was pumped from the skimmer after the towing was complete. Because oil recovery efficiency is computed from the oil-water mixture pumped during the tow, the oil collection efficiency could not be computed for this run.
4. 20 cSt oil @ 38°C used for all tests.

*above water, **below water

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TABLE 52. COMPARISON OF SKIMMER PERFORMANCE, STATIONARY MODE (JO 18)

Skimmer	Test oil viscosity cSt @ 38°C	Maximum ORR $\times 10^{-2} m^3/hr$	Disk speed or belt speed rpm	RE %
Komara Miniskimmer	10	59	139	43.1
Lockheed Clean Sweep Model 150F	10	34	20.1	93.3
Sea Hawk	20	98		41.3
JBF DIP 100	10	250	50^3	99

Notes:

1. No waves.
2. All tests conducted with hosing.
3. Independent of backplate opening.

TABLE 53. COMPARISON OF SKIMMER PERFORMANCE, ADVANCING MODE (JO 18)

Skimmer	Test oil viscosity cSt @ 38°C	Maximum ORR $\times 10^{-2} m^3/hr$	Disk speed or belt speed rpm	RE %	TE %
Komara Miniskimmer	10	130	125	33.4	50.6
Lockheed Clean Sweep Model 150F	10	32	15.1	85.8	30.4
Sea Hawk	20	79		51.4	33.6
JBF DIP 100	10	61	24.2^4	99	42.4

Notes:

1. Tow speed, 0.494 knots.
2. No waves.
3. Oil slick thickness, 2.4 mm.
4. For the JBF DIP 1001, the backplate openings were 51 mm and 152 mm.

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TABLE 54. OIL LOSS RATE OF WHITTAKER EXPANDI-BOOM (JO 18)

Test no.	Nom. wave ht. m	Tow cond.	Tow vel. kts.	Test time min	Vol. of oil ret. m^3	Lat. dist. covered by init. slick m	Init. slick thk. mm	Oil loss rate $m^3/hr/m$	Oil loss rate %/min
B -1	Aborted								
B -2	0		1.481	3.27	56.6	6.2	147	9.8	19.1
B -3	0		1.234	3.92	94.2	7.2	90	4.2	9.50
B -4	0		0.988	5.32	140.7	9.1	43	0.4	1.16
B -5	0		1.234	3.92	64.7	5.4	90	6.4	14.5
B -6	0		1.234	4.28	106.7	6.1	60	2.6	6.75
B -7	0		1.234	4.08	132.9	6.1	60	1.1	6.98
B -8	0.15	HS*	0.494	10.48	141.8	8.1	25	0.1	0.52
B -9	0.15	HS	0.988	3.634	130.0	5.4	90	1.6	7.16
B-10	0.15	HS	1.234	2.97	34.9	4.6	147	13	25.9
B-11	0.3	HS	0.494	6.97	134.3	9.1	43	0.6	1.50
B-12	0.3	HS	0.988	3.62	122.1	5.4	90	2.3	5.13
B-13	0.45	FS*	1.234	2.47	45.8	6.2[1]	147[1]	14	28.2
B-14	0.45	FS	0.494	6.33	137.6	8.1	25	0.4	1.3
B-15	Aborted								
B-16	0.45	FS	0.988	3.57	106.7	5.4[1]	90[1]	3.5	8.10
B-17	0.45	FS	1.481	2.35	36.9	6.2[1]	147[1]	16	32.1
B-18	0	FS	1.234	3.08	81.8	6.1	60	5.7	14.8

Notes:

1. Not measured, but estimated by comparison with other data.
2. 0.6 m^3 of 20 cSt @ 38°C.

*HS - head seas, FS - following seas

TABLE 55. REPEATABILITY DATA OF SKIMMERS, ADVANCING MODE (JO 18)

	Komara Miniskimmer Tests K-32 through 34	Lockheed Clean Sweep Model 150F, Tests L-15 through 24
No. of data points	3	4
Average oil collection rate $\times 10^{-2} m^3/hr$	107	27
Standard deviation of oil collection rate, $\times 10^{-2} m^3/hr$	7.5	4.3
Standard deviation of oil collection rate expressed as percentage of its average value, %	7.0	16.0
Average collection efficiency, %	33.8	85.3
Standard deviation of collection efficiency, %	11.9	1.37
Standard deviation of collection efficiency expressed as percentage of its average value, %	35.2	1.6
Average throughput efficiency, %	41.9	25.4
Standard deviation of throughput efficiency, %	2.9	4.1
Standard deviation of throughput efficiency expressed as percentage of its average value, %	7.0	16.0

Notes:

1. Test oil, no. 2 fuel oil
2. Tow speed, 0.494 knots, no waves
3. Nominal oil slick thickness, 2.4 mm

Whittaker Boom started to lose oil at a higher tow speed and then lost oil at a lower rate.

In the presence of waves with a nominal wave height of 0.15 m, in the head seas condition, the oil loss rates of the Whittaker Boom were lower than those of the SwRI prototype boom and the Bennett Class III Navy boom.

In the presence of waves with a nominal wave height of 0.3 m, in the head seas condition, the oil loss rates of the Whittaker Expandi-Boom were lower than those of the Bennett Class III Navy boom.

JOB ORDER NO. 19 - U.S. NAVY

Dates	6-26 June 1976	
Customer	Naval Facilities Engineering Command 200 Stovall street Alexandria, VA 22332	202-545-6700
Device	DIP 3001 JBF Scientific Corporation 2 Jewel Drive Wilmington, MA 01887	617-657-4170
Reports	Nadeau, P.F. USN DIP 3001 Performance Test Program. U.S. Naval Facilities Engineering Command, Alexandria, Virginia, 1976 (Ref. 41). Nadeau, P.F. Debris Handling System for Navy Harbor Oil Spill Cleanup Operations. In: Proceedings of the 1977 Oil Spill Conference, American Petroleum Institute, New Orleans, Louisiana, 1977 (Ref. 42).	

Description of Program

The Naval Facilities Engineering Command conducted tests of the U.S. Navy DIP 3001 Oil Skimmer. As a result of this program, specific recommendations on skimming speed, belt speed setting, flow control plate opening, and use of the water spray surface enhancement systems have been provided to Navy operator training programs. Extensive underwater photography and video taping proved to be an invaluable tool in directing the program and contributed greatly to the interpretation of test results. A summary report is available from the U.S. Navy, Naval Facilities Engineering Command, 200 Stovall Street, Hoffman Building #2, Alexandria, Virginia 22332.

Conclusions

The early preparation of a test plan, a careful test design, and the meticulous implementation of measurement procedures resulted in an accurate and repeatable series of tests on the USN DIP 3001.

TABLE 56. TEST RESULTS DIP 3001 (JO 19)

Test no.	Tow speed kts	Belt speed kts	Backplate opening mm	TE* %
1	1	1	0	97
2	1	1	13	101*
3	1	1	51	94
4R	1	1	89	95
64R	1.25	1.25	89	94
9	1.5	1.5	0	103*
65R	1.75	1.5	89	85
82	1.75	1.5	0	99
13	2	1.75	0	88
60C	2	1.75	89	93
81	2.5	2.25	70	80

*Standard deviation of volumetric measurements of collected oil based on 13 calibrations runs is (±) 6% for all the data reported

TABLE 57. TEST RESULTS DIP 3001 (JO 19)

Test no.	Tow speed kts	Belt speed kts	Backplate opening mm	TE* %
23SR	1.5	1.5	89	89
23T	1.5	1.5	89	90
29T	1.5	1.5	89	93
29S	1.5	1.5	89	96
72R	1.75	2.0	89	92
74	1.75	2.0	89	91
74R	1.75	1.5	89	92
24R	2	2	89	89
30	2	2	89	94
76	2.25	2.0	57	90
77	2.5	2.25	57	77
77R	2.5	2.25	57	81

Free slick, skimmer with sweeps, aperture equal 4.5 meters

TABLE 58. TEST RESULTS DIP 3001 (JO 19)

Test no.	Tow speed kts	Belt speed kts	Backplate opening mm	TE* %
49	1	1	108	84
54	1.5	1.5	108	82
62	1.5	1.5	89	75
61	2	2	32	74

Skimmer aperture = 1.5 meters

Liberal use of the instant replay video system and of surface and underwater photography was valuable in providing inputs to the test plan, in improving the testing techniques, and in verifying the test data.

In general, the throughput efficiency of the DIP 3001 was very high. In calm conditions the efficiencies ranged from 80% at 2.5 knots to over 95% at 1 knot. In a 0.46 m to 0.76 m harbor chop the efficiencies ranged from 74% at 2 knots to 84% at 1 knot.

The primary losses up to 2.5 knot skimming speed occur only at the edges of the moving plane system where moving surfaces must come in close proximity to the stationary structures of the skimmer. It is recommended that these edge losses be minimized by fairing the structure adjacent to the moving surface of the belt assembly.

The upper limit on effective skimming speed was not attained due to limitations on the test arrangement and the oil deployment system. In order to be able to test at higher speeds, the test system would have to be modified.

The back plate opening should not exceed 8.9 mm (notch 5). The belt speed should be adjusted to within ½ knot of the skimming speed.

Water jets should be used with care at operational skimming velocities (1-3 knots). High velocity water jets submerged or on the water surface tend to entrain the oil in the water column and reduce oil collection efficiency. Water jets on the operational skimming velocities should only be used at a very low water system pressure (10.3 kPa).

A dampening plate which was installed for sea kindliness for the operating crew did not adversely affect the oil collection efficiency.

JOB ORDER NO. 20 - U.S. COAST GUARD

Dates 28 June - 6 August 1976; 25 November 1975

Customer Office of Research and Development
U.S. Coast Guard
G-DMT-4/TP54
Washington, DC 20593 202-426-1023

Devices Zero-Relative Velocity (ZRV) Sorbent Belt- Skimmer
Shell Development Company
E-1340 West Hollow Research
P.O. Box 1380
Houston, TX 77001 713-493-7094

Streaming-Fibers Skimmer
Seaward International, Inc.
6269 Leesburg Pike
Falls Church, VA 22044 703-534-3500

Cyclonet D050 Catamaran-mounted
Alsthom Atlantic, Inc.
Pollution Control Dept.
441 Gravier Street
New Orleans, LA 70130 504-581-5636

Forward-Looking Infrared Oil Detector in a UH-1
Helicopter and a P-3 Aircraft
U.S. Navy-Naval Research Labs
Ft. Belvoir, VA 22060 202-767-3683

Reports

Beach, R.L. and D.W. Durfee. Development of a Streaming-Fiber Oil Spill Control System State II-Modifications to a Large-Scale Model. CG-D-05-79. U.S. Coast Guard, Washington, DC, 1978 (Ref. 3).

Getman, J.H. Performance Tests of Three Fast Current Oil Recovery Devices. In: Proceedings of the 1977 Oil Spill Conference, American Petroleum Institute, New Orleans, Louisiana, 1977 (Ref. 24).

Description of Program

Three full-size prototypes of fast-current skimmers were evaluated for the U.S. Coast Guard. The Catamaran Hydroclone Experimental Skimmer and Separator (CHESS), Seaward International, Inc.'s Streaming Fiber Concept, and Shell Development Co.'s Zero Relative Velocity Belt Concept were tested over a wide range of device-specific and environmental variables. The test plan involved the determination of an optimum value for a given parameter, followed by testing variations of a second parameter while holding the first constant at its optimum value. Three oils provided a wide range of test fluid properties. An automated data acquisition system and computer analysis were used. For additional information, contact U.S. Coast Guard Headquarters, (G-DMT-4/TP54), Washington, DC 20593.

The combined participation of U.S. Coast Guard, EPA, Army, and Navy resulted in the evaluation of a forward-looking infrared oil spill detection and mapping system. The device was mounted on a UH-1 helicopter passing over a controlled spill of No. 2 fuel oil at various altitudes and at varying angles to the sun. The primary objective was to demonstrate the utility of the equipment and to determine performance limitations with respect to surface conditions and oil slick thickness. Additional information is available from Mr. Donald Hendrix, Ft. Belvoir, Virginia 22060.

Conclusions

The Shell ZRV large scale model performed well at fast current velocities in both calm and wave conditions. The Seaward streaming fiber device performed well at fast current velocities in calm conditions, but as configured for this test program, performed poorly in waves. The Cyclonet 050, as configured for this program, provided fair performance at medium current velocities in calm conditions, and poor performance in waves.

JOB ORDER NO. 21 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates
1-12 December 1975
19 April - 9 May 1976
16 August - 3 September 1976

Customer
Office of Research and Development
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Device
Permafloat Sea Boom, 18PFX
B.F. Goodrich Sea Products
430 S. Main Street
Cohasset, MA 02025 617-383-6000

Reports

McCracken, W.E. Hydrodynamics of a Diversionary Boom. EPA-600/2-78-075, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1978 (Ref. 36).

McCracken, W.E. and F.J. Freestone. Hydrodynamics of a Diversionary Boom. In: Proceedings of the 1977 Oil Spill Conference, American Petroleum Institute, New Orleans, Louisiana, 1977 (Ref. 37).

Description of Program

The U.S. EPA sponsored this program to study and document the near-field hydrodynamics of the trailing end of a diversionary boom. Three-dimensional flow fields were examined visually, using dye and oil droplets with a towed underwater video system designed and built as part of the program. Turbulence intensity and localized velocities were measured with a hot film anemometer. In these tests, the 30-m booms were set at an angle to the direction of tow. Failure of the boom to contain oil had previously been demonstrated as occurring near the trailing end over approximately one-third the length of the boom.

Conclusions

Through the use of newly developed turbulence measurement and underwater video capabilities, together with flow visualization techniques, certain water flow characteristics have been identified that directly affect the performance of a diversionary boom. Carefully documented data have shown that the performance of a boom angled against a current greater than 1 knot (in which an oil spill is to be diverted into a collection area) cannot be easily predicted from its performance head-on against the current (catenary configuration). Streamlined rigid booms that can be moored to maintain a near constant angle against the current, with minimal near field turbulence, should demonstrate superior performance to conventional unstreamlined flexible booms.

Near-field turbulence measurements with a constant temperature, conical shaped, hot film anemometry probe indicated a marked increase in turbulence intensity from front to back of the boom at tow speeds between 0.6 and 1.5 knots. Although localized differences in turbulence intensity were not measured either in front of or behind the boom, the underwater video camera did show vertical vortices

TABLE 59. TEST RESULTS, PERMAFLOAT SEABOOM, 18 PFX (JO 21)

Test no.	Tow speed kts	Aux. volts	RMS full scale	RMS volts	Inten. RMS/ Aux.	Probe position m* x	Probe position m* y	Probe position m* z	Probe relative to boom	Comments
1	1	2.02	0.3	0.322	4.78	0.61	1.27	0.30	Fore	
2	0.8	1.88	0.3	0.395	6.30	0.45	1.27	0.30	Fore	
3	1	2.01	0.3	0.340	5.07	0.61	1.01	0.30	Fore	
4	1	2.25	0.3	0.810	10.80	1.77	1.06	0.39	Fore	
5	1	3.94	1.0	0.430	10.91	1.82	0.91	0.39	Fore	
6	1	9.54	1.0	0.790	8.28	1.82	1.06	0.39	Fore	
7		1.10						0.39	Fore	
8	1	1.85	1.0	0.240	12.97	12.75	**	0.39	Fore	
9	1	2.18	1.0	0.320	14.68	12.75	**	0.39	Fore	
10	1.6	3.38	1.0	0.320	9.47	12.75	**	0.39	Fore	
11	2	4.05	1.0	0.270	6.67	12.75	**	0.39	Fore	
12	0.5	0.27	0.3	0.250	27.78	0.76		0.66	Aft	No filter
13	1	0.74	0.3	0.300	12.16	0.60	1.06	0.66	Aft	No filter
14	0.8	0.46	0.3	0.280	18.26	0.76	1.20	0.66	Aft	No filter
15	1	0.60	0.3	0.280	14.00	0.45	1.06	0.66	Aft	No filter
16	0.8	0.32	0.3	0.300	28.13	0.76	1.30	0.66	Aft	No filter
17	0.5	0.20	0.3	0.180	27.00	1.06	1.60	0.66	Aft	No filter
18	1.6	1.86		0.930	Run aborted					
18R	1.6	1.77	1.0	0.370	20.90	0.91	0.76	0.66	Aft	No filter
19	1.7	1.85	1.0	0.310	16.76	0.60	4.50	0.66	Aft	No filter
20	2.1	1.94	1.0	0.350	18.04	0.76	4.50	0.66	Aft	No filter
21	1.6	1.54	1.0	0.330	21.43	0.76	0.76	0.66	Aft	No filter
22	1	0.97				4.50		0.66		Calibrate
23	2.1	1.48				4.50		0.66		Calibrate
24	1.6	1.20				4.50		0.66		Calibrate
25	0.5	0.48				4.50		0.66		Calibrate
26	0.5	0.23	0.3	0.100	13.04	0.91	1.06	0.66	Aft	No filter

(Continued)

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TABLE 59. (Continued)

Test no.	Tow speed kts	Aux. volts	RMS full scale	RMS volts	Inten. RMS/ Aux.	Probe position m* x	Probe position m* y	Probe position m* z	Probe relative to boom	Comments
27	1	0.55	0.3	0.270	14.73	0.91	0.91	0.66	Aft	No filter
28	1.6	0.39	0.3	0.390	30.00	0.45	0.60	0.66	Aft	No filter
29	1.6	0.47	0.3	0.370	23.62	0.60	0.60	0.66	Aft	No filter
30	2.1	0.40	0.3	0.400	30.00	0.45	0.30	0.66	Aft	No filter
31	0.5	0.75	0.1	0.300	4.00	0.91	1.80	3.50	Aft	No filter
32	1	0.63	0.1	0.840	13.33	0.91	0.91	3.50	Aft	No filter
33					Run aborted					
34	1	0.13	0.1	0.81	62.31	1.06	0.91	3.50	Aft	No filter
35	1	0.14	0.1	0.82	58.57	1.06	0.91	3.50	Aft	No filter
36	1	1.22	0.1	0.20	1.64	1.50		0.66	Aft	
37	2	1.78	0.1	0.19	1.07	1.50		0.66	Aft	
38	0.5	0.60	0.1	0.29	4.83	1.50	1.80	0.66	Aft	
39	1	1.15	0.1	0.19	1.65	1.50		0.66	Aft	
40	2	1.73	0.1	0.20	1.16	1.50		0.66	Aft	
41	0.5	0.64	0.1	0.09	1.41	1.20	1.80	0.66	Aft	
42	1	1.24	0.1	0.40	3.23	0.91	0.91	0.66	Aft	
43	0.5	0.86	0.1	0.20	2.33	1.30	1.06	0.66	Aft	
44	2	1.77	0.1	0.51	2.88	1.50	0.76	0.66	Aft	
45	2	1.12	0.003	0.98	0.30	0.73	0.30	0.30	Fore	
45R	2	1.11	0.01	0.04	0.04	0.73	0.30	0.30	Fore	
45R^2	2	1.12	0.003	0.13	0.03	0.73	0.30	0.30	Fore	
45R^3	2	1.05	0.003	0.18	0.05	0.73	0.30	0.10	Fore	
46	2	1.08	0.003	0.18	0.05	0.73	0.30	0.66	Fore	
47	2	1.05	0.003	0.23	0.06	2.40	0.30	0.66	Fore	
47R	2	1.05	0.003	0.21	0.06	2.40	0.30	0.66	Fore	
48	2	1.04	0.003	0.22	0.06	2.40	0.30	0.30	Fore	
48R	2	1.04	0.003	0.21	0.06	2.40	0.30	0.30	Fore	

(Continued)

TABLE 59. (Continued)

Test no.	Tow speed kts	Aux. volts	RMS full scale	RMS volts	Inten. RMS/ Aux.	Probe position m* x	y	z	Probe relative to boom	Comments
49	2	1.03	0.003	0.22	0.06	2.40	0.30	0.10	Fore	
49R	2	1.02	0.003	0.23	0.07	2.40	0.30	0.10	Fore	
50R	2	1.02	0.003	0.23	0.07	2.40	0.30	0.10	Fore	Filter
51	2	0.98	0.003	0.22	0.06	2.10	0.76	0.30	Fore	Filter
51R	2	2.07	0.03	0.46	0.67	1.98	0.76	0.30	Fore	Filter
52	2	2.12	0.03	0.48	0.68	1.98	0.76	0.66	Fore	Filter
53	2	0.78	0.03	0.30	1.15	1.98	0.76	0.10	Fore	Filter
53R	2	0.74	0.03	0.35	1.42	1.98	0.76	0.10	Fore	Filter
54	2	0.70	0.03	0.27	1.17	1.60	0.60	0.10	Fore	Filter
55	2	0.70	0.03	0.26	1.11	1.60	0.60	0.30	Fore	Filter
56	2	0.79	0.03	0.25	0.95	1.60	0.60	0.66	Fore	Filter
56R	2	0.76	0.03	0.22	0.88	1.60	0.60	0.66	Fore	Dye
57	2	0.78	0.03	0.21	0.81	1.31	0.60	0.66	Fore	Dye
57R	2	0.76	0.03	0.23	0.92	1.31	0.60	0.66	Fore	No dye
58	2	0.72	0.03	0.22	0.92	1.31	0.60	0.30	Fore	Filter
59	2	0.69	0.03	0.22	0.94	1.31	0.60	0.10	Fore	Filter
60	2	0.68	0.03	0.24	1.04	1.21	0.60	0.10	Fore	Filter
61	2	0.71	0.03	0.23	0.96	1.21	0.60	0.30	Fore	Filter
62	2	0.78	0.03	0.21	0.81	0.91	0.60	0.66	Fore	Filter
63	2	0.79	0.03	0.23	0.86	0.91	0.60	0.66	Fore	Filter
64	2	0.72	0.02	0.24	1.00	0.91	0.60	0.30	Fore	Filter
65	2	0.68	0.03	0.27	1.19	0.91	0.60	0.10	Fore	Filter

TABLE 60. VIDEO DOCUMENTATION, PERMAFLOAT SEA BOOM (JO 21)

Distance from trailing edge of boom, m	Tow speed kts	Boom angle, in degrees	Oil entrainment description underwater video	Oil stream width along boom, above video, m
0-3	1.2	---	Small amounts, small droplets	0.75 at trailing edge, 0.50 at 3 m
	1.4	---	Significant amounts, larger droplets of about 6 mm diameter	0.63 at trailing edge, 0.40 at 3 m
	1.6	60	Large amounts of oil ripping off, 18-25 mm droplets at trailing edge	0.50 at trailing edge, 0.30 at 3 m
3-7	1.2	---	No droplets	0.80 at 6 m mark
	1.4	---	Droplets begin to form, approx. 3-6 mm dia.	0.75 at 6 m mark
	1.6	50	High rate of droplet formation larger size, 18 mm diameter	0.60 at 6 m mark
7-10	1.2	---	No droplet	0.43 at 9 m mark
	1.4	40	Droplets begin to form	0.50 at 9 m mark
	1.6	---	High rate of droplet formation	0.41 at 9 m mark

(Continued)

TABLE 60. (Continued)

Distance from trailing edge of boom, m	Tow speed kts	Boom angle, in degrees	Oil entrainment description underwater video	Oil stream width along boom, above video, m
10-13	1.2	---	No droplets	0.43 at 12 m mark
	1.4	---	Very few droplets	0.38 at 12 m mark
	1.6	35	Nominal rate of droplet formation	0.38 at 12 m mark
13-16	1.2	---	No droplets	0.25 at 15 m mark
	1.4	---	Slight droplet formation	0.17 at 15 m mark
	1.6	30	Nominal rate of droplet formation (3 mm diameter)	0.12 at 15 m mark
16-24	1.2	---	No droplets	0.17 at 21 m mark
	1.4	---	No droplets	0.12 at 21 m mark
	1.6	25	A few detectable droplets to 18 m mark	0.12 at 21 m mark
25-28	1.2	---	No droplets	0.12 at 25 m mark
	1.4	---	No droplets	0.08 at 25 m mark
	1.6	15	No droplets	Cannot measure

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TABLE 61. SELECTED TURBULENCE INTENSITY RESULTS, PERMAFLOAT SEA BOOM, 18 PFX (JO 21)

Test no.	Tow speed kts	Turbul. inten. %	Probe position, m x	y	z	Probe orientation relative to boom tow direction
1	1.4	2.8	2.50	0.3	0.10	Fore, parallel
2	1.2	3.5	0.50	7.0	0.18	Fore, parallel
3	1.4	2.4	0.50	7.0	0.10	Fore, parallel
4	1.4	2.8	0.50	7.0	0.10	Fore, parallel
5	1.4	2.3	0.67	17.0	0.10	Fore, parallel
6	1.4	3.4	0.67	16.0	0.10	Fore,**
7	0.5	13.0	0.91	1.0	0.66	Aft, parallel
8	1.1	14.7	0.91	0.9	0.66	Aft, parallel
9	1.6	30.0	0.45	0.6	0.66	Aft, parallel
10	1.6	12.6	0.60	0.6	0.66	Aft, parallel
11	2.1	30.0	0.45	0.3	0.66	Aft, parallel

**Perpendicular

forming in front of the boom, spaced approximately 0.3 m apart, when an oil slick was diverted along the boom at speeds above 1.5 knots. These vortices effectively entrained the oil and directed it downward into the fast stream lines, where it was entrained and swept under the boom skirt.

Analysis of all quantitative and qualitative data indicates complex flow patterns with high turbulence intensity behind the boom and localized vortices and three-dimensional eddies both upstream and downstream of the boom. All of these flow characteristics directly affect boom stability and oil slick stability at the oil/water interface, which in turn determines the performance limitations of a diversionary boom.

JOB ORDER NO. 22 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	27 September - 10 October 1976	
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817	201-321-6600
Device	MARCO Class V Skimmer MARCO Pollution Control 2300 West Commodore Way Seattle, WA 98199	206-285-3200
Report	Smith, G.F. and W.E. McCracken. OHMSETT High Seas Performance Testing: MARCO Class V Oil Skimmer. EPA-600/2-78-093, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1978 (Ref. 51).	

Description of Program

Under EPA sponsorship, the MARCO Class V device was evaluated and performance data obtained for several simulated offshore wave conditions at various tow speeds. Optimum settings were defined for filterbelt and water content was determined to provide a better definition of oil/water separator needs. An EPA technical report (EPA-600/2-78-093) is available from NTIS.

Conclusions

The oil recovery rate of the MARCO Class V skimmer rose 60%, from 13.3 m^3/hr to 21.2 m^3/hr as tow speed increased from 1 kt to 3 kt in calm water. Only a 17% increase, from 10.8 m^3/hr to 12.6 m^3/hr was found in a 0.6 m HC wave over this same tow speed range.

Changing the tow speed from 1 kt to 3 kt did not affect recovery efficiency in either calm water or in the 1.2 m HC wave. But the recovery efficiency declined 32%, from 73.6% to 36.8%, in the 0.6 m HC wave over this same speed range. Throughput efficiency declined 30%, from 98.5 % to 67.9%, as speed increased from 1 to 3 kts in calm water. A 64% TE reduction was observed in the 0.6 m HC wave and a 33% drop

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TABLE 62. SUMMARY OF RESULTS, MARCO CLASS V SKIMMER (JO 22)

Wave	Tow speed (kts)	Recovery efficiency (%)	Recovery rate m^3/hr	Throughput efficiency (%)
Calm	1	78.1	13.3	98.5
Calm	2	77.9	23.8	92.9
Calm	3	76.8	21.2	67.9
0.6 m HC	1	73.6	10.8	76.1
0.6 m HC	2	50.8	11.9	44.6
0.6 m HC	3	36.8	11.6	27.7
1.2 m HC	1	35.4	---	59.6
1.2 m HC	2	34.2	10.1	39.8
1.2 m HC	3	---	---	---

$$\text{Recovery efficiency} = \frac{\text{Oil recovered } (m^3)}{\text{Total fluid recovered } (m^3)} \times 100$$

$$\text{Recovery rate} = \frac{\text{Oil recovered } (m^3)}{\text{Total recovery time (min)}}$$

$$\text{Throughput efficiency} = \frac{\text{Oil recovered } (m^3)}{\text{Oil distributed } (m^3)} \times 100$$

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occurred in the 1.2 m HC wave. Thus, increased tow speed caused oil loss to increase in all cases.

Recovered fluid water content ranged from a minimum of 21.9% to a maximum of 65.8%. In terms of a water volume rate, this covered a range from 5.4 m^3/hr to 6.5 m^3/hr (because tests recovering large fluid volumes contained less water than tests recovering smaller fluid volumes). The addition of settling tanks between the skimmer and the separator would lower these figures considerably, since about 20% of the water in the recovered fluid separated out in 15-30 minutes.

Optimum skimmer operating settings were different for each wave height condition tested. In calm water, a filterbelt speed of 1.8 kts with the induction pump pressure setting of 5.2×10^6 N/m^2 and a tow speed of 2 kt produced the best results. A filterbelt speed of 1.25 kt and a pressure setting of 3.4×10^6 N/m^2 with a tow speed of 1 kt worked best in the 0.6 m HC wave.

It should be noted that because of limited time, this test series was severely abbreviated, with little opportunity for repeating tests.

JOB ORDER NO. 23 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	3-23 May 1976	
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817	201-321-6600
Device	Tetradyne Air Jet Skimmer Tetradyne Corporation 1681 S. Broadway Carrollton, TX 75006	214-242-1512
Report	McCracken, W.E. and S.H. Schwartz. Performance Testing of the Tetradyne High Speed Air Jet Skimmer. EPA-600/2-78-187, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1978 (Ref. 38).	

Description of Program

A prototype air jet skimmer developed for EPA was evaluated at OHMSETT. The spilled materials were first concentrated by a high velocity air stream directed at 45 degrees to the water surface, and then deflected laterally into a low-current chamber for subsequent recovery. This device was tested at speeds to 6 knots with No. 2 fuel oil, naphtha, and two lubricating stocks in thin films (0.1-1.0 mm). Recovery performance parameters were determined and related to the effects of film thickness, fluid viscosity, specific gravity, and interfacial tension under fast current conditions. An EPA report (EPA-600/2-78-187) is available from NTIS.

TABLE 63. TEST RESULTS TETRADYNE SKIMMER (JO 23)

Test no.	Fluid visc. cSt @ 13°C	Dist. rate m^3/hr	Slick thk. mm	Tow speed kts	Rec. time secs	QRR $x10^{-2}m^3$/hr	TE %
1	100	2.9	0.18	6	27	10	6.7
1R	100	3.6	0.22	6	31	2.9	1.8
4	100	3.3	0.24	5	37	4.7	2.6
7	100	0.5	0.05	4	52	3.2	12.0
10	100	1.4	0.17	3	66	3.2	13.8
11	100	1.3	0.15	3	70	25	28.4
11R	100	4.3	0.52	3	78	30	10.6
8	100	7.4	0.67	4	52	32	7.1
5	100	11.7	0.83	5	48	7.2	1.0
5R	100	5.1	0.37	5	49	4	1.4
4	100	0.4	0.03	5	44	5	16.0
3	100	13.6	0.98	5	48	15	2.8
2	100	13.5	0.87	5	32	14	2.0
12	100	7	0.84	3	65	43	12.5
12R	100	9.5	1.13	3	69	56	11.9
6	100	13.6	0.98	5	41	18	2.9
3	100	13.5	0.81	6	49	10	2.5
3R	100	13.6	0.81	6	26	18	1.9
13	7	2.4	0.29	3	79	10	8.5
13R	7	2.6	0.31	3	60	15	9.0
14	7	3.2	0.23	5	44	13	10.5
15	5	0.7	0.08	3	70	10	16.1
15R	5	2.1	0.25	3	52	12	7.0
16	5	2.8	0.20	5	41	4.3	2.2

(Continued)

TABLE 63. (Continued)

Test no.	Fluid visc. cSt @ 13°C	Dist. rate m^3/hr	Slick thk. mm	Tow speed kts	Rec. time secs	ORR $x10^{-2} m^3$/hr	TE %
17	25	2.2	0.26	3	76	22	20.8
17R	25	2.2	0.27	3	67	19	11.6
18	25	5.1	0.37	5	47	7.6	3.3
19	25	2.8	0.33	3	68	10	6.6
19R	25	3.2	0.37	3	70	9	5.4
20	25	5.7	0.41	5	42	4	1.5
21*	25	3.7	0.44	3	61	2.5	1.2

*Test number 21 was conducted with 0.3 m harbor chop waves. All other tests were in calm water. Slick width was 1.5 m, encounter was 100%

Conclusions

The test results indicate that the Tetradyne Air Jet skimmer needs further development to effectively recover thin film (approximately 0.1 mm) slicks in fast currents (4 to 6 knots). Skimmer performance deteriorated in calm water with tow speeds above 3 knots, and during a single test with the 0.3 m (height) harbor chop moving at 3 knots, performance deteriorated until the skimmer became completely ineffective.

Previous laboratory test and tow tank test results with this skimmer were not confirmed by the tests at OHMSETT. Throughput efficiency was typically below 50% and recovery rates were below 2.3 m^3/hr.

Possible reasons for the lower performance were:

1. Inadequate air supply to maintain a constant and uniform nozzle velocity greater than 12 m/s.
2. Inadequate instrument and air flow controllers to measure and maintain the air flow to the booms.
3. Inadequate oil distribution and collection techniques to accurately measure and control the rate and volume of oil laydown and removal at the end of each run.

However, despite these quantification deficiencies in thin-film testing technique, qualitative data (films, slides and observations) confirmed that even when the nozzle velocity was strong enough to cause a 0.6 m spray, the throughput efficiencies did not approach the previously reported values (80%). Stronger air velocities appeared to cause both air bubble and oil droplet entrainment at the fast-current speeds. Black and white underwater video documents this gross entrainment problem. Design changes could possibly overcome this difficulty by directing the air jet more parallel to the water surface.

Tests using a variety of test fluid thicknesses did indicate a definite performance break point at about 0.2 mm. With thinner slicks, throughput efficiency was significantly higher.

Although the experimental errors were larger than normal, order-of-magnitude changes in oil viscosity and interfacial tension did seem to affect performance significantly. As the viscosity and interfacial tension were each made larger (while the other two properties and test conditions were held constant), the throughput efficiency increased significantly. Although varying the specific gravity from 0.75 to 0.85 has no significant effect, it is felt that specific gravity above 0.85 (near 1.0) would become critical and cause excessive oil entrainment.

JOB ORDER NO. 24 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 21 April - 5 May 1976

Customer
Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817
201-321-6600

Device
Coastal Waters Five-Bar Gates
Warren Springs Laboratory Dept. of Industry
Gunnels Wood Road
Stevenage
Herts, SG1 2BX, England
(0438) 3388

Report
Smith, G.F. and W.E. McCracken. Techniques for Mixing Dispersants with Spilled Oils. EPA-600/2-78-138, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1978 (Refs. 34, 46, 52).

Description of Program

The effective use of some oil spill dispersants requires the addition of mixing energy to the dispersant-treated slick. The EPA sponsored a test program to evaluate various methods of energy application including the use of fire hose streams, outboard motors mounted on work boats, and the five-bar gate--a pallet-like device towed on the surface behind vessels of opportunity. Three test fluids with different interfacial tensions were used. Droplet penetration was documented via underwater photography. The five-bar gate was modified to provide significantly greater overall penetration. A report (EPA-600/2-78-128) is available from NTIS.

Conclusions

The following conclusions were made from this test:

1. The OHMSETT modification of the five-bar gate proved to be the most effective device for breaking up a 1 mm thick oil slick into droplets, as measured by the depth of droplet penetration.
2. There was no clear relationship between interfacial tension, tow speed, or waves, and droplet penetration depth that was applicable to all four test devices.
3. Penetration depths measured with the five-bar gate were in good agreement with previous experimental work done in the United Kingdom.

To put these conclusions in proper context, it should be recognized that several potentially important variables were held constant--slick thickness, oil specific gravity, and oil viscosity. Testing the effects of these variables is recommended for future work.

In general, as speed increased, performance increased for each device, passed through an optimum, and then decreased. The deepest droplet penetration of the unaltered oil (when no waves were present) was observed at a speed of 3 knots for the fire hoses and at 4 knots for the boat and motor and for the five-bar gate. Towing the

TABLE 64. FIRE HOSE DATA (JO 24)

				Wave		
Test no.	Tow speed kts	Oil IFT dynes/cm	height m	length m	period secs	Droplet penetration cm
1	2	18	Calm			76.2
2	3	18	Calm			121.9
3	4	18	Calm			61.0
4	5	18	Calm			25.4
5	5	18	0.3	13.7	4	25.4
6	2	8	Calm			20.3
7	3	8	Calm			20.3
8	4	8	Calm			20.3
9	5	8	Calm			25.4
10	5	8	0.3	13.7	4	30.5
11	2	2	Calm			35.6
12	3	2	Calm			40.6
13	4	2	Calm			30.5
14	5	2	Calm			20.3
15	5	2	0.3	13.7	4	30.5
18	5	18	0.3HC*			20.4
19	5	8	0.3HC			25.4
20	5	2	0.3HC			20.3

*HC = harbor chop

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TABLE 65. BOAT AND MOTOR DATA (JO 24)

Test no.	Velocity kts	Oil IFT dynes/cm	Wave height m	 length m	 period secs	Droplet penetration cm
1	2	18	Calm			38.1
2	3	18	Calm			27.9
3	4	18	Calm			125.0
4	5	18	Calm			35.6
5	5	18	0.3	13.7	4	30.0
6	2	8	Calm			81.3
7	3	8	Calm			116.8
8	4	8	Calm			61.0
9	5	8	Calm			66.0
10	5	8	0.3	13.7	4	33.0
11	2	2	Calm			61.0
12	3	2	Calm			61.0
13	4	2	Calm			50.8
14	5	2	Calm			20.3
15	5	2	0.3	13.7	4	50.8
18	5	18	0.3HC*			20.3
19	5	8	0.3HC			35.6
20	5	2	0.3HC			50.8

*HC = harbor chop

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TABLE 66. FIVE-BAR GATE DATA (JO 24)

Test no.	Tow speed kts	Oil IFT dynes/cm	Wave height m	Wave length m	Wave period secs	Droplet penetration cm
1	2	18	Calm			20.3
2	3	18	Calm			25.4
3	4	18	Calm			35.6
4	5	18	Calm			20.3
5	5	18	0.3	13.7	4	38.1
6	2	8	Calm			35.6
7	3	8	Calm			20.3
8	4	8	Calm			20.3
9	5	8	Calm			20.3
10	5	8	0.3	13.7	4	20.3
11	2	2	Calm			40.6
12	3	2	Calm			
13	4	2	Calm			30.5
14	5	2	Calm			30.5
15	5	2	0.3	13.7	4	30.5
18	5	18	0.3HC*			20.3
19	5	8	0.3HC			30.5
20	5	2	0.3HC			20.3

*HC = harbor chop

TABLE 67. MODIFIED FIVE-BAR GATE DATA (JO 24)

Test no.	Tow speed kts	Oil IFT dynes/cm	Wave height m	Wave length m	Wave period secs	Droplet penetration cm
16	2	18	Calm			greater than 91.4
17	4	18	Calm			greater than 244.0

modified five-bar gate at 4 knots caused oil droplets to penetrate to the tank bottom (2.4 m); therefore, optimum speed and maximum penetration depth for this device could not be obtained in this test tank.

Droplet penetration was generally not affected by wave action. When regular waves of 0.3 m height and 13.7 m length were present, depth of droplet penetration of unaltered oil was not affected when using fire hoses, increased for the standard five-bar gate, and decreased when using the boat and motor. Lowering the IFT to 18 dynes/cm and using the regular waves, greater droplet penetration was observed for the fire hoses and the boat and motor, with no effect seen for the five-bar gate. In the presence of a 0.3 m harbor chop, the depth of oil droplet penetration decreased for the boat and motor, but was unaffected for the other devices.

Lowering of IFT from 18 to 2 dynes/cm also did not produce a general trend in device performance. Fire hoses produced less penetration, but the five-bar gate produced more penetration. More penetration was also observed with the boat and motor at speeds under 3 knots and less penetration was observed at speeds from 3 to 5 knots. Because of time considerations, the modified five-bar gate was not tested with this test mixture.

JOB ORDER NO. 25 - U.S. ENVIRONMENTAL PROTECTION AGENCY, U.S. NAVY

Dates

18 October - 31 December 1976

Customer

Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Civil Engineering Laboratory
U.S. Naval Construction Battalion Center
Port Hueneme, CA 93043 805-982-5435

Device

Mechanized Sorbent Deployment & Retrieval System (MSORS)
Ocean Design Engineering Corp.
600 East Ocean Blvd.
Long Beach, CA 90802 714-979-8782

Reports

Brunner, D.E. MSORS Performance Testing Summary. TM-M-54-77-1, U.S. Naval Civil Engineering Laboratory, Port Hueneme, CA, 1977 (Ref. 13).

Brunner, D.E., J.J. Der, and D. Hall. An Offshore Mechanized Sorbent Oil Recovery System Using Vessels of Opportunity. In: Proceedings of the 1977 Oil Spill Conference, American Petroleum Institute, New Orleans, Louisiana, 1977 (Ref. 14).

Description of Program

The Mechanized Sorbent Oil Recovery System was developed by the Naval Civil Engineering Laboratory to meet the requirement for an air transportable offshore recovery system. This full size, prototype device was tested at OHMSETT to determine its capability for recovering oil in various conditions of waves and speed, to identify problem areas in system design and to allow comparison of this system with other devices intended for offshore oil recovery. The system consisted of a sorbent chip broadcaster, deck conveyors, harvester, and regenerator. A technical memorandum (TM-M-54-77-1) was prepared by Mr. Donald E. Brunner, Civil Engineering Laboratory, Naval Construction Battalion Center, Port Hueneme, California 93043.

JOB ORDER NO. 26 - U.S. NAVY

Dates 4-15 October 1976

Customer
Naval Facilities Engineering Command
200 Stovall Street
Hoffman Building #2
Alexandria, VA 22332 202-545-6700

Devices
Navy Standard Boom
Seaward International, Inc.
6269 Leesburg Pike
Falls Church, VA 22044 703-534-3500

PAA Boom
Pollution Abatement Associates
5643 Paradise Drive, Suite 7
Corte Madera, CA 94925 415-924-8587

Report None

Description of Program

The Naval Facilities Engineering Command tested prototype sections of two oil booms. The first was designed by Seaward International, Inc. Three classes of this boom were evaluated, each with different freeboard, draft, and floatation dimensions. Additionally, two tension members (cable or chain) were evaluated in calm, harbor chop, and regular wave surface conditions. A second boom evaluated during this project was designed and manufactured by Pollution Abatement Associates, Inc. Adjustable boom end angle connectors, tension members, tow-point positions, and external tension line bridling were varied and evaluated for optimum performance. For additional information, contact Mr. Paul Hubbell, Naval Facilities Engineering Command, 200 Stovall Street, Hoffman Building #2, Alexandria, Virginia 22332.

JOB ORDER NO. 27 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 1-24 September 1976

Customer
Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

TABLE 68. TEST RESULTS NAVY STANDARD OIL BOOM (JO 26)

Test no.	Oil visc. cSt @ 11°C	Oil dist. vol. m^3	Tow speed range kts	H x L m x m	Boom class	Tension member	Critical tow speed kts	Mode* of failure
				CATENARY				
2	None		0-2.2	0x0	II	chain	2.2	SU
3	None		0-2.2	0x0	II	chain	2.2	SU
4	None		0-1.2	0.30 HC	II	chain	1	SP
5	None		0-0.8	0.30 HC	II	chain	0.2	SP
6	None		0-0.8	0.15 HC	II	chain	0.5	SP
7	70	1.34	0-0.8	0x0	II	chain	0.8	SH
8	70	1.34	0.0.7	0.15 HC	II	chain	0.25	SP
							0.7	EN
9	70	1.34	0-0.5	0.30 HC	II	chain	0.3	SP
10	70	1.34	0-0.5	0.45 HC	II	chain	0.25	SP
11	None		0-2	0x0	I	chain	none	none
12	None		0-2	0x0	I	chain	2	SP
13	None		0-0.5	0.45 HC	I	chain	0.0	SP
14	None		0	0.30 HC	I	chain	0.0	SP
15	70	1.33	0-0.7	0x0	I	chain	0.7	SH
16	70	1.32	0-0.25	0.15 HC	I	chain	0.25	SP
17	None		0-2.2	0x0	I	cable	2.2	SU
18	None		0-0.75	0.30 HC	II	cable	0.25	SP
19	None		0-1.25	0x0	II	cable	2.3	SU
20	70	1.32	0-0.7	0x0	II	cable	0.7	SH
21	70	1.32	0-0.4	0.30 HC	II	cable	0.25	SP
22	70	1.32	0-0.5	0.30 HC	II	cable	0.0	SP
23	None		0-0.5	0.30 HC	II	cable	0.4	SP

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TABLE 68. (Continued)

Test no.	Oil visc. cSt @ 11°C	Oil dist. vol, m^3	Tow speed range kts	H x L m x m	Boom class	Tension member	Critical tow speed kts	Mode* of failure
				CATENARY				
24	70	1.32	0-0.5	0.30 HC	II	cable	0.25	SP
25	None		0-2.25	0x0	III	chain	2.25	SU
26	None		0.0.75	0.45 HC	III	chain	0.6	SP
27	None		0-2.3	0x0	III	chain	2.3	SU
28	None		0-0.75	0.30 HC	III	chain	0.6	SP
29	70	1.32	0-0.8	0x0	III	chain	0.75	EN
30	70	1.32	0-0.5	0.30 HC	III	chain	0.4	SP
31	70	1.32	0-0.5	0.45 HC	III	chain	0.5	SP
32	None		0-1.0	0.30x5.2x1.9	III	chain	2.0	SU
33	None		0-1.75	0.6x4.9x2.0	III	chain	none	none
34	None		0-1.9	0.6x4.9x2.0	III	chain	2.0	SU
35	None		0-2.3	0x0	II	chain	2.3	SU
36	None		0-1.5	0.6x4.9x2.0	II	chain	1.4	SP
37	70	1.32	0-0.75	0x0	II	chain	0.7	EN
38	70	1.32	0-0.6	0.6x4.9x2.0	II	chain	0.6	EN
39	70	1.32	0-0.6	0.6x4.9x2.0	II	chain	0.6	EN
40	70	1.32	0-0.7	0.3x2.7x1.5	II	chain	0.5	SP

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TABLE 68. (Continued)

Test no.	Oil visc. cSt @ 11°C	Oil dist. vol. m^3	Tow speed range kts	H x L m x m	Boom class	Tension member	Critical tow speed kts	Mode* of failure
				CATENARY				
41	None		0-2.25	0.3x2.7x1.5	II	chain	2.25	SU
42	None		0-2.25	0.6x4.9x2.0	II	chain	2.25	SU
43	70	1.32	0-1.5	0.6x4.9x2.0	II	chain	0.7	EN
49	70	1.32	0-0.7	0.15 HC	I	chain	0.6	EN
50	70	1.32	0-0.1	0.30 HC	I	chain	0.25	SP
				DIVERSIONARY				
44	None		0-2.25	0x0	II	chain	none	none
45	70		0-1.7	0x0	II	chain	none	none
46	70	1.32	0-1.75	0x0	II	chain	1.75	EN
47	None		0-0.1	0.30 HC	II	chain	0.5	SP
48	70	1.32	0-0.75	0.30 HC	II	chain	0.5	SP

Note: Slick thickness was 3 mm for all of above tests.
*Mode of failure = SPlashover, SUbmarining, ENtrainment, SHedding

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TABLE 69. TRANSDUCER INSTRUMENTATION TEST RESULTS NAVY STANDARD OIL BOOM (JO 26)

Test no.	Tow speed kts	Wave condition H (m)	Boom class	Freeboard tilt degrees	Immersion cm	Freeboard cm	Draft cm	Tow tension N
				CATENARY				
6	0.4	0.15 m HC	II	17.5	22.6	9.6	68.5	
	0.5	0.15 m HC	II	21.0	21.6	10.4	66.1	222.6
	0.7	0.15 m HC	II	21.0	22.6	9.4	67.1	445.2
	0.8	0.15 m HC	II	21.5	23.9	8.2	68.0	556.0
7	0.5	Calm	II	16.5	13.5	18.4	60.1	222.6
	0.6	Calm	II					222.6
8	0.25	0.15 m HC	II	18.5	14.0	17.3	60.5	89.2
9	0.25	0.30 m HC	II	21.0	13.7	19.0	57.5	66.7
	0.4	0.30 m HC	II	18.5	13.0	19.7	57.9	222.6
	0.3	0.30 m HC	II	21.0	13.0	18.4	58.0	110.8
	0.35	0.30 m HC	II	19.5	13.6	19.4	57.8	110.8
10	0.25	0.45 m HC	II	21.0	18.0	13.7	62.8	
11	0.7	Calm	I	14.5	22.9	9.5	39.0	
	0.9	Calm	I					110.8
	1.2	Calm	I					222.6
	1.4	Calm	I					333.4
	1.6	Calm	I					445.2
	2.0	Calm	I	8.5	22.9	9.7	39.2	889.4
12	2.0	Calm	I					1,001.2
	2.1	Calm	I	18.5	25.1	7.2	38.4	1,222.8
	1.9	Calm	I	21.0	23.4	8.7	39.7	1,112.0
	2.0	Calm	I					1,112.0
13	0.25	0.45 m HC	I	21.5	28.4	4.0	42.7	
16	1.5	0.15 m HC	I					333.4

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TABLE 69. (Continued)

Test no.	Tow speed kts	Wave condition H (m)	Boom class	Freeboard tilt degrees	Immersion cm	Freeboard cm	Draft cm	Tow tension N
				CATENARY				
17	2.0	Calm	II					1,668.0
	2.25	Calm	II					2,334.8
18	0.75	0.30 m HC	II					333.4
19	2.0	Calm	II					2,669.2
	2.25	Calm	II		9.9			4,670.6
	2.5	Calm	II					4,893.2
20	0.5	Calm	II					110.8
	0.6	Calm	II		3.0			110.8
21	0.4	0.30 m HC	II		9.4			110.8
23	0.4	0.30 m HC	II	14.5	19.1	13.1	66.2	222.6
	0.5	0.30 m HC	II	29.5	16.0	14.5	56.8	222.6
24	0.25	0.30 m HC	II	16.4	7.0	27.3	50.3	
	0.5	0.3 m HC	II	15.7	19.3	12.9	66.0	
25	0.2	Calm	III					0.0
	0.6	Calm	III					1,222.8
	1.5	Calm	III					3,002.6
	2.0	Calm	III					5,560.0
26	0.5	0.45 m HC	III					333.4
	0.75	0.45 m HC	III					889.4
	0.6	0.45 m HC	III					556.0
27	1.5	Calm	III	1.0	NA	32.7	84.1	
29	0.75	Calm	III	8.0	9.4	23.1	92.6	
30	0.4	0.30 m HC	III	21.5	6.9	24.1	84.6	
31	0.25	0.45 m HC	III	22.0	9.1	23.8	85.9	
	0.5	0.45 m HC	III	20.0	7.4	21.8	86.8	

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TABLE 69. (Continued)

Test no.	Tow speed kts	Wave condition H (m)	Boom class	Freeboard tilt degrees	Immersion cm	Freeboard cm	Draft cm	Tow tension N
				CATENARY				
35	0.5	Calm	II					110.8
	1.0	Calm	II					445.2
	2.0	Calm	II					2,446.6
	2.3	Calm	II					3,669.4
36	0.5	0.6 m x 4.9 m	II					110.8
	0.75	0.6 m x 4.9 m	II					445.2
36	1.0	0.6 m x 4.9 m	II					889.4
	1.2	0.6 m x 4.9 m	II					1,222.8
	1.5	0.6 m x 4.9 m	II					1,557.2
	1.4	0.6 m x 4.9 m	II					1,557.2
	1.3	0.6 m x 4.9 m	II					1,334.6
49	0.25	0.15 m HC	I					89.2
	0.5	0.15 m HC	I					110.8
	0.6	0.15 m HC	I					155.9
	0.7	0.15 m HC	I					177.5
50	0.7	0.30 m HC	I					222.6
				DIVERSIONARY				
44	1.0	Calm	II					1,228
	1.5	Calm	II					2,001.4
	2.0	Calm	II					2,224.0
	2.25	Calm	II					3,113.4

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TYPING GUIDE SHEET

TABLE 69. (Continued)

Test no.	Tow speed kts	Wave condition H (m)	Boom class	Freeboard tilt degrees	Immersion cm	Freeboard cm	Draft cm	Tow tension N
				DIVERSIONARY				
45	1.0	Calm	II					1,112.0
	1.2	Calm	II					1,557.2
	1.4	Calm	II					1,557.2
	1.6	Calm	II					1,890.6
46	1.25	Calm	II					1,445.4
	1.6	Calm	II					2,001.4
	1.75	Calm	II					2,113.2
47	0.75	0.30 m HC	II					445.2
	1.75	0.30 m HC	II					2,446.6
	1.0	0.30 m HC	II					889.4
48	0.25	0.30 m HC	II					445.2
	1.0	0.30 m HC	II					666.8
	0.75	0.30 m HC	II					889.4

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(4-76)

Device High Current Streamlined Boom/Skimmer
Ultrasystems, Inc.
2400 Michelson Drive
Irvine, CA 92715 714-752-7500

Report Folsom, B.A. Development of a High Current Oil Boom/Skimmer, EPA-600/2-80-140. U.S. Environmental Protection Agency, Cincinnati, Ohio, 1980 (Ref. 20).

Folsom, B.A. and C. Johnson. Development of a High Current Oil Boom/Skimmer for Inland Waterways. In: Proceedings of the 1977 Oil Spill Conference. American Petroleum Institute, New Orleans, Louisiana, 1977 (Ref. 21).

Description of Program (Also see Job Order 15)

In 1975 and 1976, a slightly submerged slotted hydrofoil with an attached sump was evaluated by the EPA for use as a high current skimmer. The device was designed and fabricated by Ultrasystems, Inc. and tested as an integrated system (including a stability and floatation control mechanism). Both lubricating stock and No. 2 fuel oil in selected slick thicknesses were directed to the device under tow. Oil recovery rate, recovery efficiency, and throughput efficiency were then determined and related to the controlled independent variables. A report, (EPA-600/2-80-140) is available from NTIS.

JOB ORDER NO. 28 - U.S. NAVY

Dates 26 October - 23 November 1976

Customer Civil Engineering Laboratory
U.S. Naval Construction Battalion Center
Port Hueneme, CA 93043 805-982-5435

Device Mechanized Sorbent Deployment & Retrieval System (MSORS)
Ocean Design Engineering Corp.
600 East Ocean Blvd.
Long Beach, CA 90802 714-979-8782

Report Brunner, D.E. MSORS Performance Testing Summary. TM-M-54-77-1, U.S. Naval Civil Engineering Laboratory, Port Hueneme, California, 1977 (Ref. 13).

Brunner, D.E., J.J. Der, and D. Hall. An Offshore Mechanical Sorbent Oil Recovery System Using Vessels of Opportunity. In: Proceedings of the 1977 Oil Spill Conference, American Petroleum Institute, New Orleans, Louisiana, 1977 (Ref. 14).

TABLE 70. TEST RESULTS MSORS (JO 28)

Run	speed	Waves H (m)	Oil dist. m^3/hr	Tot. fluid rec. m^3	RE %	ORR m^3/hr	TE %
1	2.0	Calm	74	0.5	61	11	23
2	2.0	Calm	24	0.4	56	9	53
6	3.0	0.5 HC	24	0.2	54	6	25
11	2.0	0.5 HC	21	0.5	36	---	50
16	1.0	0.5 HC	22	1.0	38	---	55
A -1	2.0	0.5 HC	14	0.3	40	6	57
A -1R2	2.0	0.5 HC	16	0.4	36	8	55
A -2R	3.0	0.5 HC	23	0.4	36	10	39
A -3	4.0	0.5 HC	33	0.3	41	15	34
A -4	2.0	Calm	18	0.3	30	5	33
A -5R	3.0	Calm	26	0.3	44	9	35
A -6R	4.0	Calm	37	0.4	46	15	54
A -7	2.0	1.2 HC	17	0.4	24	5	42
A -7R	2.0	1.2 HC	18	0.2	20	3	21
A -8	3.0	1.2 HC	27	0.2	30	5	22

Description of Program: (Also see Job Order 25)

The Mechanized Sorbent Oil Recovery System was developed by the Naval Civil Engineering Laboratory to meet the requirement for an air transportable offshore recovery system. This full size, prototype device was tested at OHMSETT to determine its capability for recovering oil in various conditions of waves and speed, to identify problem areas in system design and to allow comparison of this system with other devices intended for offshore oil recovery. The system consisted of a sorbent chip broadcaster, deck conveyors, harvester, and regenerator. A technical memorandum (TM-M-54-77-1) was prepared by Mr. Donald E. Brunner, Civil Engineering Laboratory, Naval Construction Battalion Center, Port Hueneme, California, 1977.

Conclusions

The system actually performed quite well in light of the mechanical difficulties encountered, the problems inherent in the design of certain components and the test procedures necessitated by the limitations posed by the test facility.

The capability of the sorbent concept to recover oil in high waves and current was demonstrated.

Chip loss from the system posed a real problem during the test. While much of this loss would not occur in an at-sea environment, means must be developed to prevent chip loss beneath the harvester.

The performance of the sorbent was adversely affected by the use of fire hoses and by prolonged soaking in the test tank. Both of these factors contributed to the water saturation of the chips and removal of the oil presoak.

The convergence of the herding channel limits the speed at which the system can be operated and contributes to the loss of sorbent.

The design of the regenerator (which required the oil/water mixture to pass through the belt twice) contributed to the emulsification of the recovered fluid and may have contributed to the emulisification present in the chips.

The use of the B.F. Goodrich boom to simulate the side of the vessel was unsatisfactory because of the flexibility of the boom and its small freeboard and draft.

JOB ORDER NO. 29 - U.S. ENVIRONMENTAL PROTECTION AGENCY, U.S. COAST GUARD

Dates 29 November - 6 December 1976

Customer Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Office of Research and Development
U.S. Coast Guard
G-DMT-4/TP54
Washington, DC 20593 202-426-1023

Device OMI Zero Relative Velocity Skimmer (ZRV)
Oil Mop, Inc.
Engineers Road
P.O. Drawer P
Belle Chasse, LA 70037 504-394-6110

Report Breslin, M.K. Performance Testing of Oil Mop Zero Relative Velocity Oil Skimmer. EPA-600/7-78-060, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1978 (Ref. 5).

Description of Program

This test program was initiated by the EPA and U.S. Coast Guard to determine the capabilities of the Oil Mop Mark II-9D, catamaran-mounted skimmer. The principle of operation was based on oil being adsorbed onto oleophilic fibers woven into a rope. Test speeds approached 6 knots to determine the device's fast current potential with two oils distributed as controlled slicks in various surface conditions. As a result of the program, design improvements were suggested and operational guidelines established. An EPA report (EPA-600/7-78-060) is available from NTIS.

Conclusions

The following conclusions were drawn from the evaluation of the test data and observations of equipment performance.

The OMI-ZRV skimmer recovered oil best at slow speeds (2 kt) in calm water with the belt running slightly faster or slower than the tow speed. But before a definite appraisal of the system can be made, several items support the need for further testing:

1. Because of initial set-up problems, weather conditions, and problems with the device, only two days of testing were possible. Consequently, there was no chance to analyze the data collected and refine testing techniques.

2. The device's recovery efficiency improved toward the end of each test run, suggesting that the samples were collected too early in the test runs and before steady state conditions were achieved.

3. Recovery time was not recorded until the second day of testing; it was noticed then that a discrepancy (less than 15 seconds) could exist between it and distribution time.

4. A definite time for starting the rope mops could not be established. Such unknowns make design analysis difficult.

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TABLE 71. OIL MOP INC. MARK II-9D (ZRV) SKIMMER (JO29)

Test no.	Tow speed kts	Wave cond. H (m)	Dist. vol. m^3	Dist./rec. time/time sec/sec	Dist. rate m^3/hr	Oil rec. m^3	ORR m^3/hr	RE %	TE %
1-2	3	Calm	0.50	59.8	30	0.47	3	8.7	12.4
2-1	3.5	Calm	0.50	50.0	36	0.102	7.3	24.1	27.2
2-2	2.5	Calm	0.44	60.2	26	0.117	7	22.7	35.8
5-1	3	Calm	0.82	60.6/56.8	49	0.088	5.6	23.6	14.2
3-1	2	0.6 m HC	0.35	60.1/63.6	21	0.084	4.8	14.8	35.5
3-2	3	0.6 m HC	0.50	60.2/50.0	30	0.066	4.8	10.4	20.7
5-1R	3	Calm	0.83	60.0/48.2	50	0.104	7.7	19.7	18.6
5-2	3	Calm	01.39	59.7/62.8	84	0.132	7.6	24.1	13.3

Sunvis 7 light oil used for all tests.
Slick thickness was 3 mm for tests 1-2, 2-1, 2-2, 3-1, and 3-2.
Slick thickness was 5 mm for tests 5-1 and 5-1R.
Slick thickness was 8 mm for test 5-2.
Mop tow speed was 3 kts for all tests.

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The design shows promise but is still in the developmental stage. The rope-mop and squeezer components of the skimmer have been used successfully to recover oil from water at a fixed location with little or no current. Successfully incorporating these components into a moving system will require further study and modifications of the present device. Such modifications should include a different shape for the catamaran hulls and larger rope-mop drive engines. Gradual transition between the main hull to the bow and stern would produce less headwave, less drastic oil channeling, and less entrainment of missed oil after the device passes. The rope-mop drive units used during testing could not process the rope mops fast enough and sometimes stalled during operation.

JOB ORDER NO. 30 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 1 July 1976 to Present

Customer Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Devices
1. Video Bridge
2. Vacuum Bridge
3. Auxiliary Bridge
4. Video Bridge Update
5. Vacuum Bridge Update
6. Wave Flap Strengthening
7. Wave Generator Repair
8. Catamaran Hull Repair
9. Hazardous Material Safety Equipment
10. Oil Storage Facility
11. Gangplank
12. Beach-o-Meter Oil Thickness Gauge
13. Johnson Drum Sampler

Report None

Description of Program

This program is used to accrue costs for OHMSETT modifications and special construction items. Costs are then charged against users who need the items for testing.

SECTION 7

TESTS PERFORMED IN 1977

JOB ORDER NO. 31 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	16-27 May 1977	
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817	201-321-6600
Device	Air Jet Boom Hydronautics, Inc. 7210 Pindell School Road Laurel, MD 20810	301-776-7454
Report	Cohen, S.H. Design, Fabrication, and Testing of the Air Jet Oil Boom. EPA-600/7-79-143, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1979 (Refs. 16, 17).	

Description of Program

The Hydronautics, Inc. Air Jet Boom, designed and built under EPA contract, was evaluated at OHMSETT. The device was rigged in the diversionary configuration to direct an air stream at an angle to the water surface to divert oncoming oil. Test variables included tow speeds, oils, and wave conditions as well as such device-specific operating parameters as nozzle angle, air pressure, and diversionary angle. An EPA report (EPA-600/7-79-143) is available from NTIS.

Conclusions

The Air-Jet Boom has the potential to provide an effective means of controlling oil slicks on inland waterways under conditions that normally preclude successful deployment of commercially available booms or other recently developed prototypes.

Performance tests at OHMSETT have shown that the Air-Jet Boom is capable of diverting thin oil slicks (2 millimeter) in 3.0 knot currents with 15 percent loss when deployed at 30 degrees to the flow. Moreover, the addition of waves has only a nominal effect on performance; steep, irregular waves (up to 1.2 m high) increased losses by only 5 to 10 percent compared to experience in calm water, and in some cases there was no perceptible increase.

Additional operational features that distinguish the Air-Jet Boom from other booms are its shallow draft and low drag. The shallow draft is significant in two ways:

TABLE 72. SUMMARY OF ESTIMATED DIVERSION AIR JET BOOM PROOF TESTS (JO 31)

		Diversion (Estimated)		
Boom Angle	Speed (Knots)	Calm Water	Regular Waves*	Harbor Chop**
30 degrees (2-mm slick)	2.0	100%	95%	85%
	2.5	80%	75%	70%
	3.0	60%	55%	---
45 degrees (1.5-mm slick)	1.0	100%	95%	95%
	1.5	90%	70%	---
	2.0	75%	60%	75%

*Regular Wave 0.2 m high, 5.5 m long, 1.9 sec period

**Harbor Chop 0.6 m high

TABLE 73. SUMMARY OF ESTIMATED DIVERSION AIR JET BOOM PERFORMANCE TESTS (JO 31)

		Diversion (Estimated)		
Boom Angle	Speed (Knots)	Calm Water	Regular Waves*	Harbor Chop**
20 degrees (3-mm slick)	2.0	100%	---	90%
	3.0	90%	90%	80%
	4.0	70%	70%	---
30 degrees (2-mm slick)	2.0	100%	95%	90%
	2.5	90%	---	---
	3.0	85%	---	80%
45 degrees (1.5-mm slick)	1.0	100%	---	100%
	1.5	100%	80%	80%
	2.0	75%	---	---

*0.2 m high, 5.5 m long, 5.5 sec. period

**1.2 m high

first, floating debris is readily swept beneath the boom without snagging, and second, the boom can be deployed over shoals or in shallow streams where conventional booms will not even float. Low drag means that rigging and deployment is somewhat easier and that the natural tendency to form a catenary planform shape, which hinders diversion performance with conventional booms, is less pronounced.

The Air-Jet Boom features unique capabilities for diverting oil spills in fast current and waves. It relies upon a shore-based compressor to supply air, however, which restricts the choice of deployment sites to those having reasonable road access for the compressor(s). Of course, skimming gear and recovered oil storage tanks have the same type of limitation, so a spill recovery system using an Air-Jet Boom for slick diversion should not be unduly handicapped in this regard. Consideration should also be given to the length of air-supply hose that will be needed to reach from the compressor to the boom, as the pressure drop in an excessively long hose will cause a falloff in boom performance.

JOB ORDER NO. 32 - U.S. ENVIRONMENTAL PROTECTION AGENCY, U.S. COAST GUARD, U.S. NAVY, U.S. DEPARTMENT OF ENERGY

Dates 18 April - 28 October 1977

Customers
Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Office of Research and Development
U.S. Coast Guard
G-DMT-4/TP54
Washington, DC 20593 202-426-1023

Naval Facilities Engineering Command
200 Stovall Street
Hoffman Building #2
Alexandria, VA 22332 202-545-6700

Civil Engineering Laboratory
U.S. Naval Construction Battalion Center
Port Hueneme, CA 93043 805-982-5435

Division of Environmental Control Technology
U.S. Department of Energy
MS-E201
Washington, DC 20545 301-353-5486

Devices
OMI Zero Relative Velocity (ZRV) Skimmer
Oil Mop, Inc.
Engineers Road
P.O. Drawer P
Belle Chasse, LA 70037 504-394-6110

Cyclonet D050 Skimmer
Alsthom-Atlantic Inc.
441 Gravier Street
New Orleans, LA 70130 504-581-5636

CLOWSOR Skimmer
Anti-Pollution, Inc.
P.O. Box 885
1319-1325 Front Street
Morgan City, LA 70380 504-384-9517

Mark 6E Skimmer
Bennett Pollution Controls, Ltd.
119 Charles Street
Vancouver, B.C. V7H 1S1, Canada 604-929-5451

Reports

Urban, R.W. and D.J. Graham. Performance Tests of Four Selected Oil Spill skimmers. EPA-600/2-78-204, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1978 (Ref. 53).

Urban, R.W. and S.H. Schwartz. Performance Tests of Four Selected Oil Spill Skimmers. In: Proceedings of the 1979 Oil Spill Conference, American Petroleum Institute, Los Angeles, California, 1979 (Ref. 54).

Description of Program

A jointly sponsored program of the U.S. Coast Guard, EPA, Department of Energy, and Navy evaluated the Oil Mop Zero Relative Velocity Skimmer, Cyclonet D050, Bennett Mark 6E, and CLOWSOR skimmers. This project provided performance data over a wide range of controlled test conditions for commercially available skimmers. Optimum operating parameters were defined. A report (EPA-600/2-78-204) is available from NTIS and a 16 mm color, sound movie entitled, "Performance Tests of Four Selected Skimmers," is available from the Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

Conclusions

Oil Mop ZRV Skimmer

During the period 18 to 29 April 1977, 44 oil pickup performance data runs were conducted with the Oil Mop ZRV skimmer. A total of 17 tests were conducted with high viscosity (heavy) oil and 27 tests using low viscosity (light) oil.

Best performance. The highest average values of the three skimmer performance parameters, TE, RE, and ORR, for each of the heavy and light oil tests are summarized in Tables 74 and 75.

TABLE 74. HIGHEST AVERAGE RESULTS - OIL MOP ZRV, HEAVY OIL (JO 32)

Performance parameter	Highest average result	Tow speed knots	Wave condition H x L (m x m)
TE	71%	1	0
RE	77%	2	0
ORR	13 m^3/hr	3	0

TABLE 75. HIGHEST AVERAGE RESULTS - OIL MOP ZRV, LIGHT OIL (JO 32)

Performance parameter	Highest average result	Tow speed knots	Wave condition H x L (m x m)
TE	78%	2	0
RE	70%	2	0
ORR	17.3 m^3/hr	4	0

The above values are the highest averages of all individual test results at the same test tank conditions. Although certain test results may be higher than the values listed above, the use of an average is more representative of the true value since it compensates for random experimental errors.

Operating limits. Based upon the behavior observed in these tests, the operating limits for this skimmer appear to depend upon three factors:

1. Mechanical design of the bow mop wringer and stern roller assemblies.
2. Contact time between oil slick and mops as the skimmer travels over the slick.
3. Large surface area of the drip pan between stern rollers and bow wringer.

Regarding the first item, the bow wringer assembly was unable to rotate the mops with heavy oil at faster than 3 knots without jamming, due to mop strands adhering to the squeeze rollers. Following the conclusion of this test series, the manufacturer resolved this problem through a redesign of the bow wringer assembly. Oil loss occurred in light oil tests in the form of a rooster tail as the mops were pulled aboard the skimmer over the stern roller at forward speeds above 3 knots.

TABLE 76. OIL MOP ZRV RESULTS - HEAVY OIL AVERAGE VISCOSITY 3000 cSt (JO 32)

Test no.	Tow speed knots	Oil dist. rate m^3/hr	Slick thick mm	Waves H x L (m x m)	Encounter %	Rel. mop speed knots	RE %	TE %	ORR m^3/hr
11	2	16.3	3	0	100	0	76	46	5.8
11A	2	18.4	3	0	100	0	74	59	8.6
12	2	17	3	0	100	0	79	69	9
13	2	17.7	3	0	100	*	84	69	9.7
13A	2	17	3	0	100	*	83	65	9
13B	2	13.6	3	0	100	*	67	49	5
13C	3	25.6	3	0	100	0	72	57	11.9
13D	3	24.5	3	0	100	0	78	70	13.7
15	1	7.7	3	0	100	0	85	---	---
15A	1	7.2	3	0	100	0	60	78	4.3
15B	1	7.7	3	0	100	0	51	65	4
15C	1	8.6	3	0	100	0	46	71	4.7
19	1	8.2	2	0.6HC	50	0	63	---	---
19A	1	9.5	3	0.6HC	75	0	41	69	4
18B	1	9.1	3	0.6HC	65	0	38	78	30.6
19C	1	7.3	3	0.6HC	70	0	33	85	3.2
20	1	7.5	3	0.6HC	45	0	28	87	2.2

*max w/o slippage

TABLE 77. OIL MOP ZRV RESULTS - LIGHT OIL OF AVERAGE VISCOSITY 9 cSt

Test no.	Tow speed knots	Oil dist. rate m^3/hr	Slick thk. mm	Waves H x L (m)x(m)	Encounter %	Rel. mop speed knots	RE %	TE %	ORR m^3/hr
6B	2	19.7	3	0	100	0	65	84	12.6
25	2	15.6	3	0	100	0	63	62	7.6
25A	2	18.4	3	0	95	0	75	90	12.6
25B	2	18.8	3	0	100	0	78	78	11.5
26	2	18.4	3	0	100	(+.5)	65	61	9
26A	2	18.4	3	0	100	(+.5)	64	52	7.6
27	2	18.1	3	0	100	(+1)	69	52	7.6
27A	2	18.1	3	0	100	(+1)	59	58	8.3
27B	2	19.9	3	0	100	(+1)	59	51	7.9
29	4	33.1	3	0	95	0	64	72	18
29A	4	33.8	3	0	100	0	60	62	16.9
30	5	42	3	0	100	0	49	49	16.2
30A	5	44	3	0	100	0	52	44	15.1
28	5	40.8	3	0	90	0	44	36	10.4
35	2	17.5	3	0.6 HC	95	0	50	58	7.6
35B	2	17.9	3	0.6 HC	95	0	57	86	11.2
35C	2	17.9	3	0.6 HC	90	0	58	88	11.2
35A	2	19.5	3	0.6 HC	90	(+.5)	50	56	7.6
36	4	34	3	0.6 HC	75	0	42	62	12.6
36A	4	32.4	3	0.6 HC	90	0	48	72	16.6
36B	4	33.8	3	0.6 HC	95	0	42	52	13.3
38	4	32.9	3	0.6 HC	75	(+.5)	37	52	10
37	5	43.6	3	0.6 HC	80	0	36	42	11.9
32	2	16.8	3	0.6x12.4	55	0	53	---	---
32A	2	17	3	0.8x12.4	50	0	69	---	---
33	4	31.8	3	0.8x12.4	85	0	40	51	10.8
33A	4	32.4	3	0.8x12.4	80	0	49	79	16.2

Regarding the second factor, the oil contact time limits the pickup rate of oil at high skimmer forward speeds. The number of test runs was insufficient to establish this upper speed limit precisely. The maximum speed for which data was obtained was 5 knots. At skimmer forward speeds of 5 knots, the oil-to-mop contact time is only 4.8 seconds between the bow and stern of the 11.7 m long catamaran where the mops are lifted out of the water.

Oil loss from the third factor was noted during tests with heavy oil. The loss was caused by slippage of the mops over the squeeze rollers at the bow due to the large drag of the oil-laden mops against the drip pan as they were pulled forward by the bow wringer assembly.

Cyclonet 050 Skimmer

Oil collection performance tests were conducted with the Cyclonet 050 skimmer during the period 22 August to 2 September 1977. A total of 26 data runs were conducted with high viscosity (heavy) oil and 19 data runs with low viscosity (light) oil.

Best Performance. The highest average values of the three skimmer performance parameters, TE, RE, and ORR, for each of the heavy and light oil tests are listed along with key test conditions in Tables 78 and 79 below.

TABLE 78. HIGHEST AVERAGE RESULTS - HEAVY OIL TESTS, CYCLONET 050 (JO 32)

Performance parameter	Highest average value	Tow speed knots	Wave condition H x L (m x m)
TE	34%	1.5	0
RE	27%	1.5	0.18 x 8
ORR	3.2 m^3/hr	1.5	0

TABLE 79. HIGHEST AVERAGE RESULTS - LIGHT OIL TESTS, CYCLONET 050 (JO 32)

Performance parameter	Highest average value	Tow speed knots	Wave condition H x L (m x m)
TE	20%	1.5	0
RE	12%	3	0
ORR	2.2 m^3/hr	3	0

TABLE 80. CYCLONET 050 TEST RESULTS - HEAVY OIL OF AVERAGE VISCOSITY 550 cSt (JO 32)

Test no.	Tow speed knots	Oil dist. rate m^3/hr	Slick thk. mm	Waves H x L (m)x(m)	Encounter %	Rel. mop speed knots	RE %	TE %	ORR m^3/hr
20	1	8.6	1.6	0	100	12.2	22	32	2.9
20A	1	6.5	1.2	0	100	13	17	34	2.2
16	1.5	9	1.0	0	95	13.3	20	31	2.9
19	1.5	10.1	1.2	0	100	14	18	25	2.5
19A	1.5	9	1.0	0	100	13	25	36	3.2
26	1.5	10.1	1.1	0	95	16.6	25	43	4.3
18	2	11.2	1.0	0	95	13	17	21	2.2
18B	2	12.6	1.1	0	100	13.3	8	8	1.1
18C	2	10.8	0.9	0	100	13.3	19	23	2.5
21	3	15.8	1.0	0	98	13.7	16	14	2.2
21A	3	17.3	1.0	0	100	13.3	28	21	3.6
22	1.5	10.1	1.2	0.18x8	95	6.8	42	30	2.9
22A	1.5	9	1.1	0.18x8	95	14.4	13	21	1.8
23	3	16.2	1.0	0.18x8	100	10.1	8	2	1.1
23A	3	15.8	0.9	0.18x8	100	10.8	10	7	1.1
28	1.5	10.1	1.2	0.15 HC	95	16.9	7	13	1.4
28A	1.5	9.4	1.1	0.15 HC	98	16.6	9	16	1.4
15R	1.5	23.8	2.9	0	90	13	50	30	7.2
25	2	34.2	3.1	0	90	18.7	14	9	2.9
24	3	46.1	2.8	0	95	19.1	19	9	4
29	1.5	4	*	0	98	13	7	24	10.8
30	1.5	5	*	0	98	13	15	40	2.2
32	1.5	1.4	*	0	100	13	6	50	.7
32A	1.5	2.9	*	0	98	13	15	70	2.2
31	3	3.6	.8	0	100	11.2	2	6	.4
31A	3	4.7	1.2	0	100	12.2	3	7	.4

*Single slick only.

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TABLE 81. CYCLONET 050 TEST RESULTS - LIGHT OIL OF AVERAGE VISCOSITY 22 cSt (JO 32)

Test no.	Tow speed knots	Oil dist. rate m^3/hr	Slick thk. mm	Waves H x L (m)x(m)	Encounter %	Rel. mop speed knots	RE %	TE %	ORR m^3/hr
33	1.5	10.4	1.3	0	90	17.6	10	19	2.2
33A	1.5	10.1	1.2	0	90	16.6	12	22	2.2
34	2	11.2	1.0	0	95	16.9	7	11	1.4
34A	2	12.2	1.1	0	98	16.9	9	13	1.4
35	3	18.7	1.1	0	98	16.9	12	11	2.2
35A	3	18	1.1	0	95	17.3	13	13	2.2
36	1.5	26.3	3.1	0	85	18.4	13	11	2.9
36A	1.5	27	3.2	0	90	17.6	14	10	2.9
37	3	50.4	3.0	0	90	18.4	10	4	2.2
37A	3	55.4	3.3	0	95	18.7	9	3	1.8
40	1.5	9.4	1.1	0.15 HC	95	18	3	6	.7
40B	1.5	8.6	1.0	0.15 HC	90	15.8	3	6	.7
41	1.5	8.6	1.0	0.18x8	95	15.8	13	25	2.2
41A	1.5	7.9	1.0	0.18x8	95	15.1	5	10	1.1
43	1.5	4.7	*	0	100	11.2	47	112	5
43A	1.5	7.6	*	0	100	11.5	62	97	7.2
43B	1.5	8.3	*	0	100	11.5	66	89	7.6
43C	1.5	13	*	0	100	11.5	90	80	10.4
44	3	8.3	*	0	100	11.2	57	78	6.5

*Oil injected into Cyclonet

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The above values are the highest of the averages of all individual test results calculated for each test tank condition. Although certain test results may be higher than the values listed above, the use of an average is more representative of the true value since it compensates for unavoidable random experimental errors. For an overall indication of the trends of the three performance parameters, the average values of results are plotted in the Test Results section for each test tank condition used. (See Tables 80 and 81).

Operating Limits. Two major oil loss mechanisms were consistently observed in both calm water and wave tests, and placed a definite upper limit on performance. These oil loss mechanisms were:

1. Vortex shedding of oil out the bottom of the convergent side wall near the point of attachment to the hydrocyclone.
2. Losses underneath the hull of the Zodiac boat at all speeds.

A number of preliminary tests were conducted to quantify the oil losses from each of the above two mechanisms. Based upon these tests, modifications were made before any of the data reported here was collected.

Even with the modifications installed, test data show that the speed range limits of the device in calm water are from 1.5 to 3 kts, with TE values below 10% in a 0.15 m harbor chop wave condition and a tow speed of 1.5 kts for light oil.

CLOWSOR Skimmer

During the period 6 to 16 September 1977, 32 oil collection performance data tests were conducted with the CLOWSOR skimmer. A total of 21 of these tests were conducted with high viscosity (heavy) oil and 11 tests conducted with low viscosity (light) oil.

Best Performance. The highest average values of the 3 performance parameters TE, RE, and ORR for each of the heavy and light oil tests are listed in Tables 82 and 83.

TABLE 82. HIGHEST AVERAGE RESULTS - CLOWSOR, HEAVY OIL (JO 32)

Performance parameter	Highest average value	Tow speed knots	Wave condition
TE	96%	0	0
RE	91%	0	0
ORR	21.6 m^3/hr	0	0

TABLE 83. HIGHEST AVERAGE RESULTS - CLOWSOR, LIGHT OIL (JO 32)

Performance parameter	Highest value value	Tow speed knots	Wave condition
TE	61%	1.5	0
RE	65%	0	0
ORR	12.2 m^3/hr	0	0

Operating Limits. Depending upon slick thickness, the CLOWSOR showed itself capable of achieving very high oil recovery rates. The highest rate recorded during these tests was with heavy oil in which the slick thickness reached a maximum of approximately 300 mm during the test and the oil recovery rate reached a maximum value of 23 cubic meters per hour. An oil recovery rate in excess of this value could have been attained had the supplied pumps been able to offload the skimmer at a higher flowrate.

There are 4 factors which limit the performance of the CLOWSOR skimmer:

1. Currents in excess of 0.5 knot.
2. Waves in excess of 0.3 metre harbor chop.
3. Paddle speeds greater than 2.5 rpm.
4. Oil with viscosity less than about 20 cSt.

Bennett Mark 6E Skimmer

Best Performance. During the period 17 to 28 October 1977, a total of 99 data runs were performed with the Bennett Mark 6E skimmer. A total of 62 runs were conducted with heavy oil and 37 runs with light oil. The test results at each set of test conditions were averaged to take into account random testing errors. The highest of these averages for each type of oil is presented in Tables 86 and 87 below. The use of the highest average test results over all test conditions is more representative of the true value because random experimental errors are averaged out.

TABLE 86. HIGHEST AVERAGE RESULTS - BENNETT MARK 6E, HEAVY OIL (JO 32)

Performance parameter	Highest value value	Tow speed knots	Wave condition H, m
TE	95%	3	0
RE	88%	1	0.3 HC
ORR	24.5 m^3/hr	2	0

TABLE 84. CLOWSOR TEST RESULTS - HEAVY OIL OF AVERAGE VISCOSITY 1900 cSt (JO 32)

Test no.	Tow speed knots	Oil dist. rate m^3/hr	Slick thk. mm	Waves H x L (m)x(m)	Total test oil down m^3	Paddle speed rpm	RE %	TE %	ORR m^3/hr
7A	0	0	51	0	0.6	*	87	96	6.5
7B	0	0	51	0	0.6	*	83	96	5.4
7C	0	0	51	0	0.6	*	80	96	6.8
8	0	0	13	0	0.1	*	58	91	1.4
8A	0	0	13	0	0.1	*	82	91	7.6
9	0	0	26	0	0.3	*	78	---	---
9A	0	0	26	0	0.3	*	84	93	9.4
10A	0	0	26	0.2x8.0	0.3	*	7	71	5
10B	0	0	26	0.2x8.0	0.3	*	11	72	5.4
11A	0	0	26	0.3 HC	0.3	*	35	66	4
12	0	20.5	0-51	0	3.5	*	84	97	17.3
13	0	59	0-300	0	5.6	*	91	96	21.6
14B	0	5.8	0-22	0	0.5	*	94	66	2.5
14C	0	5.8	ND	0	0.9	*	93	71	ND
15A	0	11.5	0-37	0	0.9	*	94	---	---
15B	0	11.5	0-30	0	0.9	*	89	---	---
17	.5	11.5	4	0	0.9	2.4	88	85	6.1
17A	.5	11.5	4	0	0.9	2.5	89	88	5.4
18	.75	16.9	4	0	0.8	1.4	86	99	12.6
19	.5	11.5	4	0.3 HC	0.9	2.4	40	78	6.1
19A	.5	11.5	4	0.3 HC	0.9	2.4	35	78	ND

*Paddle speed varied by operator.

TABLE 85. CLOWSOR TEST RESULTS - LIGHT OIL OF AVERAGE VISCOSITY 14 cSt (JO 32)

Test no.	Tow speed knots	Oil dist. rate m^3/hr	Slick thk. mm	Waves H x L (m)x(m)	Total test oil down m^3	Paddle speed rpm	RE %	TE %	ORR m^3/hr
23	0	5.8	ND	0	0.5	2.4	60	63	ND
23A	0	5.8	0-22	0	0.5	3.5	67	81	2.9
24	0	11.5	0-51	0	0.9	2.5	66	36	4.7
24A	0	11.5	0-20	0	0.9	2.5	65	49	8.6
25	0	68.4	0-341	0	4.6	ND	47	50	10.8
25A	0	68.4	0-275	0	3.8	ND	52	74	13.7
20	.5	11.5	4	0.3 HC	0.9	ND	16	41	4
20A	.5	11.5	4	0.3 HC	0.9	ND	17	43	4
21	.5	11.5	4	0	0.9	ND	63	67	5.4
21A	.5	11.5	4	0	0.9	3.5	61	50	2.9
22	.75	16.9	4	0	0.8	ND	64	65	6.5

TABLE 87. HIGHEST AVERAGE RESULTS - BENNETT MARK 6E, LIGHT OIL (JO 32)

Performance parameter	Highest average value	Tow speed knots	Wave condition H, m
TE	90%	1.5	0
RE	64%	2.5	0
ORR	8.3 m^3/hr	2	0

Operating Limits. The performance of the Bennett Mark 6E skimmer as determined by throughput efficiency appears to be limited by three factors:

1. Wave-following ability of the bow ramp.
2. Degree of turbulence inside the skimmer as a function of forward skimmer speed and specific positions of the forward and aft gill doors, and bow ramp depth.
3. Physical properties of oil.

When operating in waves, the bow ramp must be lowered to remain below the water surface as the skimmer heaves. Tests showed that the wave-following ability of the ramp was affected by wave steepness and attempts to lower the ramp in the 0.3 m harbor chop produced increased turbulence in the area of the collection belt, thus causing more oil droplets into suspension and reduced throughput efficiencies.

Sensitivity to oil properties and velocity was observed in the comparison of speeds at which TE on the average dropped to below 50%. With heavy oil, this occurred at a forward speed of 5.5 knots, while with light oil at about 2.5 knots. Operational effectiveness is thus determined by the tendency of specific oils to become mixed into the water column, exiting the skimmer via the forward and aft gill doors.

The effectiveness of this device with respect to TE is directly related to the stability of the oil/water interface and is seen to diminish as turbulence increases.

Mechanical Limits. The performance of the device is directly sensitive to operator controlled skimmer settings of the bow ramp and gill doors. Several test runs were required for each condition to find the right combination of settings. The oil offloading rate was limited due to squeeze belt mechanical problems and the pressure of the squeeze belt was not sufficient to force all the oil from within the collection belt. This overload of the collection belt with excess oil was more pronounced with light oil than with heavy oil. In heavy oil tests, oil was removed from the collection belt primarily by a doctor blade assembly.

TABLE 88. BENNETT MARK 6E TEST RESULTS - HEAVY OIL OF AVERAGE VISCOSITY 3000 cSt (JO 32)

Test no.	Tow speed knots	Oil dist. rate m^3/hr	Slick thk. mm	Waves H x L m x m	Enc. %	Bow	Door setting Mid	Aft	RE %	TE %	QRR m^3/hr
7	1	6.7	3.0	0	100	1.04	0.47	0.06	83	85	5.8
7A	1	6.7	3.0	0	100	1.09	0.50	0.06	86	106	7.2
8	2	13.5	3.0	0	100	1.09	0.40	0.06	82	103	13.7
8A	2	13.6	3.1	0	100	1.09	ND	0.06	83	73	14
8B	2	13.9	3.1	0	100	1.09	0.38	0.06	66	73	10.1
9C	2.5	16.8	3.0	0	90	0.99	0.35	0.06	58	78	11.5
10	3	20.1	3.0	0	97	0.94	0.16	0.06	86	98	18.7
10A	3	19.4	2.9	0	98	0.97	0.24	0.06	74	92	20.5
11	3.5	23.3	3.0	0	98	0.94	0.25	0.06	76	83	18.7
11A	3.5	24.2	3.1	0	100	0.91	0.28	0.06	75	92	22
12	4	25.8	2.9	0	90	0.86	0.23	0.06	81	81	18.7
12A	4	27.3	3.1	0	96	0.81	0.23	0.06	80	65	16.6
13	4.5	30.2	3.0	0	96	0.81	0.30	0.06	76	81	23
13A	4.5	30.5	3.0	0	96	0.84	0.28	0.06	75	58	16.6
14A	5	38.9	3.3	0	95	0.84	0	0.06	70	59	20.2
14B	5	32.4	2.9	0	96	0.84	0.05	0.06	81	66	20.2
15	5.5	36	3.0	0	100	0.83	0.05	0.06	80	50	18
16	6	42.1	3.2	0	100	0.83	0.10	0.06	76	43	18
16A	6	39.6	3.0	0	100	0.83	0.10	0.06	66	14	5.4
17C	1	7.5	3.4	0.18x7.9	98	1.06	0.41	0.06	83	100	7.2
17D	1	6.9	3.1	0.18x7.9	100	1.06	0.41	0.06	80	103	7.2
18	2	13.9	3.1	0.18x7.9	98	1.06	0.41	0.06	77	34	4.3
18A	2	12.8	2.9	0.18x7.9	98	1.06	0.41	0.06	82	39	4.7
18B	2	13.1	3.0	0.18x7.9	95	0.99	0.43	0.06	75	30	3.6
18C	2	11.8	2.7	0.18x7.9	95	ND	0.30	0.13	80	51	5.8
18D	2	13.2	3.0	0.18x7.9	95	0.99	0	0.27	80	55	6.7
18E	2	13	2.9	0.18x7.9	95	1.17	0	0.27	80	57	6.7

(Continued)

TABLE 88. (Continued)

Test no.	Tow speed knots	Oil dist. rate m^3/hr	Slick thk. mm	Waves H x L m x m	Enc. %	Bow	Door setting Mid	Aft	RE %	TE %	ORR m^3/hr
19	1.5	2.83	3.1	0.18x7.9	95	1.06	0	0.27	81	67	6.5
19A	1.5	2.86	3.1	0.18x7.9	95	1.06	0	0.27	82	65	6.1
20A	1	1.78	2.9	0.3 HC	98	0.99	0.50	0.06	88	89	5.8
20B	1	6.7	3.0	0.3 HC	98	1.02	0.50	0.06	87	88	5.8
21A	1.5	2.77	3.0	0.3 HC	100	1.02	0.50	0.27	84	67	6.7
21B	1.5	2.80	3.0	0.3 HC	100	1.02	0.60	0.06	86	59	5.8
21C	1.5	2.80	3.0	0.3 HC	100	1.02	0	0.27	86	95	9.4
21D	1.5	2.80	3.0	0.3 HC	100	1.02	0	0.27	84	75	7.6
22	2	3.60	2.9	0.3 HC	100	1.02	0	0.27	83	81	10.4
22A	2	3.81	3.1	0.3 HC	100	0.99	0	0.27	86	72	9.7
23	2.5	4.87	3.2	0.3 HC	100	1.02	0	0.27	82	84	11.2
24	3	5.65	3.1	0.3 HC	100	1.02	0	0.27	79	57	11.5
25	3.5	6.46	3.0	0.3 HC	100	1.02	0	0.27	76	42	9.7
27	1.5	2.83	3.1	0.6 HC	95	1.07	0	0.27	76	50	4.7
28	2	3.74	3.0	0.6 HC	98	1.07	0	0.27	76	53	6.7
29	2.5	4.66	3.0	0.6 HC	100	1.07	0	0.27	75	49	7.9
30	3	5.89	3.2	0.6 HC	100	1.07	0	0.27	76	51	10.4
31	2	13.04	10.6	0	100	1.04	0.30	0.06	80	43	20.2
31A	2	14.28	11.6	0	100	0.99	0	0.27	83	76	28.8

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TABLE 89. BENNETT MARK 6E TEST RESULTS - LIGHT OIL OF AVERAGE VISCOSITY 32 cst (JO 32)

Test no.	Tow speed knots	Oil dist. rate m^3/hr	Slick thk. mm	Waves H x L m x m	Enc. %	Door setting			RE %	TE %	QRR m^3/hr
						Bow	Mid	Aft			
40A	1	1.91	3.1	0	100	0.97	0.36	0.06	59	76	5.4
45	1	6.7	3.1	0	100	0.91	0.36	0.08	68	88	5.8
41	2	3.82	3.1	0	100	0.99	0.36	0.06	52	43	5.8
41A	2	3.73	3.0	0	100	0.97	0	0.27	55	53	6.7
41B	2	3.84	3.1	0	100	0.97	0.25	0.15	57	41	5.8
42	3	5.72	3.1	0	100	0.97	0.15	0.27	52	27	7.2
43	1.5	3.36	3.6	0	100	0.97	0.25	0.27	60	76	9.4
43A	1.5	2.99	3.2	0	100	1.09	0.25	0.27	57	65	6.7
43B	1.5	2.80	3.0	0	100	0.97	0.25	0.27	55	73	6.7
44	2	3.69	3.0	0	100	1.09	1.15	1.27	50	39	5
50A	1	1.75	2.9	0	100	0.97	0	0.27	55	59	5
50B	1	2.31	3.7	0	100	0.97	0	0.27	71	81	6.7
51	1.5	2.83	3.1	0	100	0.97	0	0.27	60	90	9.4
51A	1.5	3.14	3.4	0	100	0.97	0	0.14	51	67	7.6
51C	1.5	2.77	3.0	0	100	0.97	0	0.15	58	71	6.7
52	2	4.08	3.3	0	100	0.91	0	0.14	64	63	9.4
52A	2	4.27	3.5	0	100	0.91	0	0.05	59	43	6.5
52B	2	4.15	3.4	0	100	0.94	0	0.05	63	65	9.7
53	2.5	4.24	2.8	0	100	0.93	0	0.03	68	54	7.9
53A	2.5	4.77	3.1	0	100	0.91	0	0.03	60	37	6.1
60	1	1.80	2.9	0.6 HC	100	1.09	0	0.08	43	26	1.4
60A	1	1.76	2.9	0.6 HC	100	1.04	0	0.16	30	17	1.1

(Continued)

TABLE 89. (Continued) (JO 32)

Test no.	Tow speed knots	Oil dist. rate m^3/hr	Slick thk. mm	Waves H x L m x m	Enc. %	Bow	Door setting Mid	Aft	RE %	TE %	ORR m^3/hr
61	1.5	2.86	3.1	0.6 HC	100	1.52	0	0.27	40	12	1.1
61A	1.5	3.18	3.4	0.6 HC	100	1.07	0	0.27	50	20	2.2
61B	1.5	2.89	3.1	1.6 HC	100	1.07	0	0.27	52	27	2.5
70	1.5	2.80	3.0	0.3 HC	100	1.02	0	0.27	55	41	4
70A	1.5	2.95	3.2	0.3 HC	100	1.02	0	0.27	60	48	5
71	2	13.6	3.1	0.3 HC	100	1.02	0	0.15	55	39	5
71A	2	4.36	3.5	0.3 HC	100	1.02	0.05	0.15	40	38	5.8
72	1	4.06	6.5	0.3 HC	100	1.02	0.05	0.27	58	59	8.6
72A	1	1.80	2.9	0.3 HC	100	1.02	ND	0.27	51	59	4

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JOB ORDER NO. 33 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	28 March - 5 April 1977 11-15 April 1977 23-30 September 1977	
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817	201-321-6600
Device	Permafloat Boom, 18 PFX B.F. Goodrich Sea Products 430 Main Street Cohasset, MA 02025	617-383-6000
Report	Breslin, M.K. Boom Configuration Tests for Calm Water, Medium Current Spill Diversion. EPA-600/2-78-186, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1978 (Ref. 6).	

Description of Program

This study was conducted by the EPA to determine the effects of boom angle, length and rigging configuration on the diversion of oil floating on moving streams. The B.F. Goodrich 18 PFX boom was rigged as a nozzle-shaped configuration to achieve optimum containment at tow speeds above 2 kts. Different nozzle exits were investigated to minimize oil entrainment and subsequent spreading. An EPA report (EPA-600/2-78-186) is available from NTIS.

Conclusions

The boom configurations described here were rigged with the boom at rest with respect to the OHMSETT tank water. The boom was then towed through the tank water to simulate a current. In the field, the boom must be rigged in a current, a more difficult situation. Any field use of the boom configurations shown in this report will go far more smoothly if they can be planned and practiced before an oil spill occurs.

If a straight diversionary boom is used to divert oil, parachute mooring lines are necessary. The lines should be of small diameter to avoid generating standing waves and thus entraining oil. Small cusps form in the boom at the points of attachment and cause some shedding, but not as much as the drastic cusp at the trailing end of a boom without parachute lines. The lines also stabilize the boom, and permit higher speeds before stability failure (e.g., boom diving or planing) occurs.

The angle of the boom to the current directly affects performance. The more perpendicular to the current the boom stands, the lower the speed at which oil loss and boom stability failure occur. When the perpendicular component of the current against a diversionary boom approaches 1 knot, oil shedding increases dramatically.

TABLE 90. SINGLE DIVERSIONARY BOOM TEST RESULTS (JO 33)

Test no.	Boom angle (deg.*)	Tow speed knots	Failure points	Oil beneath (%)	Oil away from rear (%)	Type of loss **	Slick thk. (mm)***	Comments
A-1	32	1/4	Cusps	1	0	SH	1.94	No vortices formed along boom
A-2	32	1.6	Cusps, some along boom	5	0	SH	1.99	No vortices formed along boom
A-3	32	1.8	Cusps, intermittently along boom	10	5	SH	1.72	Vortices after boom passes. None along skirt.
A-4	32	2	Cusps predominantly along boom increasing toward the end.	50	50	SH	1.68	Vortices after boom passes. None along skirt.
A-5	32	2.5	All along boom starting at 3.5 m	70	50	SH	1.48	Vortices after boom passes. None along skirt. Entrainment severe.
A-6	20	1.1	None	0	0	None	1.60	No entrainment after boom passes.
A-7	20	1.6	None	0	0	None	1.14	No entrainment after boom passes.

(Continued)

TABLE 90. (Continued)

Test no.	Boom angle (deg.*)	Tow speed knots	Failure points	Oil beneath (%)	Oil away from rear (%)	Type of loss **	Slick thk. (mm)***	Comments
A-8	20	2	Cusps	7	0	SH	1.00	Small standing waves set up by parachute lines. Small entrainment and vortices after boom passes.
A-9	20	2.5	Cusps, amount increasing down the boom	10	0	SH	1.10	Standing wave set up by line. Vortices and entrainment after boom.
A-10	20	3	Starts at 5 m (first cusps at 7 m) sheds at all cusps	30	5	SH	1.10	Standing wave with some entrainment because of lines. Entrainment and vortices after boom.

(Continued)

TABLE 90. (Continued)

Test no.	Boom angle (deg.*)	Tow speed knots	Failure points	Oil beneath (%)	Oil away from rear (%)	Type of loss **	Slick thk. (mm)***	Comments
A-11	20	3.3	All along boom	50	10	SH	1.10	Standing wave, severe entrainment. Planing failure in first section.
A-12	No lines	2	Begins at 16 m from front. Very severe.	80	50	SH	1.40	Severe entrainment and vortices following the boom. The boom was unstable at 1.5 m/s

*32-four boom sections, 20-three boom sections, **SH-Shedding, ***Based upon a 9.1 m width

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TABLE 91. DOUBLE DIVERSIONARY BOOM ("V") TEST RESULTS (JO 33)

Test no.	Boom angle (deg.*)	Tow speed knots	Failure points	Oil beneath (%)	Oil away from rear (%)	Type of loss **	Slick thk. (mm)***	Comments
B-1	20	1.1	None	0	0	None	1.12	No entrainment. No vortices.
B-2	20	1.6	None	0	0	None	1.15	Small vortices after boom.
B-3	20	2	None	0	0	None	1.15	Small vortices after boom.
B-4	20	2.5	At cusps	5	0	SH	1.07	Slight entrainment and vortices follow boom.
B-5	20	3	All along boom	10	5	SH	1.00	Entrainment begins at 6 m and continues along boom. Severe entrainment follows.
B-6	20	3.3	All along boom	30	15	SH	1.07	Entrainment begins at 6 m and continues along boom. Severe entrainment follows.

*20-two boom sections, **SH-Shedding, ***Based upon a 9.1 m width

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TABLE 92. DOUBLE DIVERSIONARY (NOZZLE) BOOM TEST RESULTS (JO 33)

Test no.	Boom con-fig.	Tow speed knots	Failure points	Oil beneath (%)	Oil away from rear (%)	Type of loss **	Slick thk. (mm)***	Comments
C-1	Nozzle (2 sec. each side)	1.1	None	0	0	None	1.09	Spreader bar at rear causing standing waves.
C-2	Nozzle	1.6	None	0	0	None	1.08	Turbulence on leading edge of nearest boom.
C-3	Nozzle	2	Small losses at 2 m	3	0	SH	1.08	Loss on nearest boom.
C-4	Nozzle	2.5	Small losses at 4 m	10	3	SH	1.10	Standing wave set up by ropes.
C-5	Nozzle	3	Losses start 3 m and continues to 7 m	15	5	SH	1.09	Front end turbulence causes failure.
C-6	Nozzle	3.3	Losses all along boom	20	7	SH	1.09	Difficult to see if failure is consistent along the boom.

(Continued)

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TABLE 92. (Continued)

Test no.	Boom con-fig.	Tow speed knots	Failure points	Oil beneath (%)	Oil away from rear (%)	Type of loss **	Slick thk. (mm)***	Comments
C-7	Nozzle with belled exit	2	Start at 4 m losses along boom	10	3	SH	1.08	Losses do not appear to be increasing along boom.
C-8	Constricted nozzle exit belled	2	Losses begin at 3.5 m and continue down boom	10	3	SH	1.08	Losses do not increase along the boom. Constricted throat increased boom angle slightly.

*20-two boom sections, **SH-Shedding, ***Based upon a 9.1 m width

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(4-76)

Few vortices formed along the boom skirt in any configuration. Oil losses were predominantly due to the shearing action of the water on the oil/water interface (shedding). Not all of the oil which passed beneath the boom skirt was lost. The horizontal action of the water passing beneath the skirt drew much of the entrained oil into a quiescent zone behind the boom. The same vortical action kept the oil from leaving the rear of the boom. The result was that the oil traveled down behind the boom and rejoined the unentrained oil at the exit.

The straight exit from the nozzle configuration, with the rear of the boom sections lifted from the water, proved to be the best shape of those tested. The exiting oil slick remained the width of the exit for about ten seconds before beginning to spread. Entrainment was minimal due to the absence of turns or sharp edges that would have caused turbulence. Even with the boom skirt tied up around the floatation, the parabolic and quarter-circle exits created too much turbulence for the oil to leave the boom without clinging to the floatation or being entrained.

Oil losses increased downstream along the boom when a straight diversionary configuration was used. Nozzle-shaped configurations appear promising since less entrainment and fewer standing vortices resulted at the exit. At 3.25 kts, the nozzle configuration lost only 7% of the encountered oil, while the 20° "V" configuration lost 15%.

The crucial area of the nozzle shape is the leading portion of the booms. The angle at which the booms at the nozzle mouth engages the water must not be too large, or turbulence which would drive the oil downward might result. During the higher tow speed tests, the strong horizontal vortices generated at the leading portions of the booms were felt further downstream and instigated oil loss. Boom stability failure at low current velocities (1.5 knots) could also result from too great an attack angle.

Observation and photo/video documentation of tests using oil are vivid and to the point. The use of hot film anemometry at OHMSETT has proven very delicate and time-consuming in boom study. Problems inherent with large-scale testing also produce problems in probe placement and protection. However, small-scale testing using hot film probes and streamers could be helpful. Systematic variation of the boom skirt depth and position might delineate areas where oil could be contained behind the boom, as well as in front.

JOB ORDER NO. 34 - U.S. DEPARTMENT OF ENERGY

Dates 7 June - 5 August 1977

Customer Division of Environmental Control Technology
U.S. Department of Energy
MS-E201
Washington, DC 20545 301-353-5486

Devices Cyclonet 100 Skimmer
Alsthom-Atlantic, Inc.
441 Gravier Street
New Orleans, LA 70130 504-581-5636

MARCO Class V Skimmer
Marine Construction & Design Co.
2399 West Commodore Way
Seattle, WA 98199 206-285-3200

Coast Guard Skimming Barrier
Offshore Devices, Inc.
Summit Industrial Park, Bldg. 53
Peabody, MA 01960 617-581-6404

Reports

Ackerman, R.A. Performance Test Results of Three Offshore Skimmers, (Ref. 1).

Lichte, H.W. Skimming Barrier Performance Evaluation, Offshore Version and Harbor Version. In: Proceedings of the 1979 Oil Spill Conference, American Petroleum Institute, Los Angeles, California, 1979 (Ref. 28).

Lichte, H.W. and M.K. Breslin. Performance Testing of Three Offshore Skimming Devices. HCP/P3241-01, U.S. Department of Energy, Washington, D.C. 1978 (Ref. 31).

Lichte, H.W. and M.K. Breslin. Performance Testing of Three Offshore Skimming Devices. EPA-600/7-78-082, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1978 (Ref. 32).

Lichte, H.W. and M.K. Breslin. Testing Skimmers for Offshore Spilled Oils. In: Proceedings of the 1978 Offshore Technology Conference, Houston, Texas, 1978 (Ref. 33).

Description of Program

The U.S. Department of Energy sponsored a program to evaluate three commercially available offshore skimmers. The Cyclonet 100, MARCO Class V, and U.S.C.G. Skimming Barrier were tested with various speeds, waves, and oil to simulate harbor and offshore environments. Results indicated the limits of performance with respect to the test tank induced parameters and determined the effects of various device-specific parameters such as device immersion depth, pump rate, and belt speed. A DOE report (HCP/P 3241-01) and an EPA report (EPA-600/7-78-082) are available from NTIS. A 16 mm color, sound movie entitled, "Capturing Spilled Energy," is available from the Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

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TABLE 93. TEST RESULTS CYCLONET 100 WITH CIRCO MEDIUM (JO 34)

Test no.	Wave	Tow speed knots	Slick thk. mm	Discharge rate m^3/hr	Pump ratio	Device position	ORR m^3/hr	RE %	TE %
1R	Calm	6	2.9	82.8	1.72	M	0.0	0.0	0.0
1R1	Calm	6	2.9	69.3	1.43	M	0.1	0.1	2.3
2	Calm	6	2.9	67.2	1.27	U	0.4	0.6	0.9
2R	Calm	6	3.0	68.6	1.35	U	0.5	0.7	0.9
3	Calm	4	2.8	44.6	1.43	U	0.6	1.4	3.3
3R	Calm	4	2.9	48.1	1.47	U	0.9	1.8	3.7
4	Calm	4	3.0	42.8	1.28	U+100	2.1	4.8	6.5
4R	Calm	4	3.0	42.2	1.28	U+100	2.2	5.1	6.8
5	Calm	4	2.9	18.7	0.57	U+195	1.4	7.5	4.7
5R	Calm	4	2.9	21.9	0.68	U+195	1.8	8.3	6.0
6	Calm	4	3.0	43.5	1.32	U+100	1.6	3.7	9.8
6R	CAlm	4	3.2	51.5	1.46	U+100	0.8	1.5	10.9
7	Calm	4	3.2	45.8	1.30	U	1.9	4.2	13.3
8	Calm	4	3.1	46.0	1.33	M	3.4	7.4	17.4
9	Calm	2	3.1	35.9	2.09	U+100	6.6	18.3	56.7
9R	Calm	2	3.0	36.6	2.2	U+100	7.1	19.4	56.8
10	Calm	2	3.0	36.1	2.15	U	0.7	1.9	8.2
10R	Calm	2	2.9	36.2	2.24	U	3.3	9.2	34.5
11	Calm	3	3.1	45.8	1.79	U	4.4	9.7	27.3
11R	Calm	3	3.2	49.2	1.82	U	2.6	5.2	21.8
12	Calm	3	2.9	48.7	2.01	U+100	8.7	18.0	53.3
13	Calm	6	3.1	63.8	1.21	U	0.0	0.0	15.9
14	Calm	6	3.2	39.8	0.78	U+195	0.5	1.2	1.0
15	Calm	4	2.9	67.5	2.11	U+100	5.4	7.9	24.1
15R	Calm	4	3.2	61.5	1.75	U+100	3.1	5.0	19.2
16	Calm	4	3.2	38.2	1.07	U+100	7.1	18.6	21.6
13R	Calm	6	2.8	59.9	1.30	U	0.6	1.0	1.4
14R	Calm	6	3.2	28.8	0.53	U+195	0.2	0.6	0.4
17	Calm	4	3.3	7.3	0.20	U+195	1.5	20.0	4.2

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TABLE 93. (Continued)

Test no.	Wave	Tow speed knots	Slick thk. mm	Discharge rate m^3/hr	Pump ratio	Device position	ORR m^3/hr	RE %	TE %
25	Calm	4	3.4	64.2	1.71		4.5	7.1	22.7
25R	Calm	4	3.2	64.7	1.79		5.2	8.1	20.3
18	Calm	6	2.8	85.8	1.82	U+195	0.3	0.4	0.9
18R	Calm	5	3.2	85.8	.60	U+195	1.3	1.5	5.2
19	Calm	5	2.9	69.1	1.70	U+100	1.1	1.6	3.0
19R	Calm	5	3.2	73.0	1.66	U+100	5.5	7.6	19.5
20	Calm	5	2.9	69.7	1.73	U+195	1.3	1.9	3.6
20R	Calm	5	3.0	68.0	1.63	U+195	1.3	1.9	3.9
21	Calm	3	3.3	45.2	1.63	U+100	7.8	17.3	51.7
21R	Calm	3	3.0	44.2	1.74	U+100	9.0	20.3	54.2
22	Calm	2	3.3	32.5	1.77	U+100	4.5	14.0	48.2
22R	Calm	2	3.1	32.5	1.89	U+100	6.0	18.4	56.1
23	Calm	2	3.0	33.3	1.98	U	1.9	5.7	21.3
23R	Calm	2	2.8	33.3	2.17	U	5.3	15.7	42.6
26	Calm	5	3.0	81.3	1.95		0.8	1.0	3.0
26R	Calm	5	3.0	72.4	1.75		0.8	1.1	3.6
27	Calm	6	2.8	54.1	1.16		0.4	0.8	3.1
27R	Calm	6	3.2	53.4	1.01		0.1	0.2	0.4

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TABLE 94. TEST RESULTS CYCLONET 100 WITH CIRCO HEAVY (JO 34)

Test no.	Wave	Tow speed knots	Slick thk. mm	Discharge rate m^3/hr	Pump ratio	Device position	ORR m^3/hr	RE %	TE %
35	Calm	6	2.5	52.8	1.27		0	0	2.3
30	Calm	4	3.0	62.3	1.85	U+100	7.8	12.5	36.7
32	Calm	6	2.8	51.5	1.09	U+100	0	0	0.3
31	Calm	4	2.9	58.5	1.79		7.3	12.6	34.9
30R	Calm	4	3.2	58.5	1.64	U+100	0.7	1.2	2.3
31R	Calm	4	3.2	58.1	1.65		4.7	15.5	20.9
32R	Calm	6	2.8	52.8	1.14	U+100	0.0	0.1	0.2
35R	Calm	6	3.0	50.8	1.01		0	0	0.2
28	Calm	2	2.8	33.5	2.13	U+100	9.0	26.9	70.0
28R	Calm	2	3.0	32.3	1.94	U+100	9.6	29.1	70.8
29	Calm	3	2.9	52.3	2.20	U+100	14.2	27.2	73.7
29R	Calm	3	3.1	49.7	1.91	U+100	15.4	31.0	68.3
33	Calm	5	2.8	73.0	1.86	U+100	0.1	0.2	0.8
28R1	Calm	2	3.3	36.4	1.99	U+100	6.8	19.0	40.4
34	Calm	5	2.8	71.9	1.84		0.4	0.7	1.3
34R	Calm	5	3.1	71.3	1.63		0.3	0.5	1.2
33R	Calm	5	3.3	73.5	1.62	U+100	0.1	0.2	0.4
30R1	Calm	4	3.2	61.1	1.72	U+100	8.3	13.7	25.4
36	Calm	3.5	2.9	61.0	2.13	U+100	12.5	20.6	46.9
36R	Calm	3.5	3.1	60.3	1.97	U+100	12.5	20.8	58.5
37	Calm	3.5	3.0	59.9	2.07		11.4	19.2	42.3
37R	Calm	3.5	2.9	59.9	2.10		11.2	18.9	60.2
38	Calm	1	3.5	20.1	2.05	U+100	3.0	15.2	64.4
40	0.6 R*	2	(No Oil)			U+100	(No Oil)		
40A	0.6 R	2	(No Oil)			U	(No Oil)		
40B	0.6 R	2	(No Oil)			D	(No Oil)		
41	0.6 R	2	3.2	32.3	1.80	D +50	0.0	0.1	0.1
41A	0.6 R	2	3.0	7.7	0.45	M	0.0	0.2	0.4

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TABLE 94. (Continued)

Test no.	Wave	Tow speed knots	Slick thk. mm	Discharge rate m^3/hr	Pump ratio	Device position	ORR m^3/hr	RE %	TE %
42	0.6 R	4	(No Oil)			M	(No Oil)		
42A	0.6 R	4	(No Oil)			U+100	(No Oil)		
42B	0.6 R	4	(No Oil)			U+100	(No Oil)		
42C	0.3 R	4	3.0	28.3	0.85	U +50	0.2	0.8	0.9
57	0.6 HC	4	3.0	33.5	1.00	U+100	0.0	0.3	0.8
57R	0.6 HC	4	3.0	37.8	1.15	U+100	0.3	0.9	1.4
61	0.6 HC	3	3.0	29.0	1.15	U+100	0.1	0.5	1.1
62	0.6 HC	3	2.9	0	0	U+100	0	0	0
63	0.6 HC	2	2.9	34.0	2.08	U+100	0.1	0.5	1.7
63R	0.6 HC	2	3.0	51.4	3.03	U+100	0.1	0.4	1.1
64	0.6 HC	2	3.1	42.1	2.45	U+100	0.1	0.4	0.1
64R	0.6 HC	2	3.0	64.5	3.87	U+100	0.1	0.3	2.2
67	0.6 HC	3	2.8	48.2	2.06	U+100	0.2	0.5	1.7
70	0.6 HC	2	2.9	34.8	2.13	U+100	0.16	0.4	2.1
71	0.6 HC	3	2.7	109.1	4.92	U+100	0.1	0.1	0.7
68	Calm	2	3.1	28.4	1.67	U+100	8.8	31.1	69.4
68R	Calm	2	2.9	35.9	2.20	U+100	9.5	26.6	82.7
69	Calm	3	2.8	48.7	2.10	U+100	12.8	27.3	78.5
69R	Calm	3	3.0	54.5	2.17	U+100	13.6	23.5	110.3
65	0.3 HC	2	2.7	45.1	2.95	U+100	0.3	0.7	4.6
65R	0.3 HC	2	3.2	49.9	2.84	U+100	0.4	0.9	4.2
66	0.3 HC	3	2.5	65.0	3.07	U+100	0.23	0.4	2.4
66R	0.3 HC	3	3.0	58.6	2.33	U+100	4.5	7.7	31.0
72	0.3 HC	2	3.1	87.7	5.15	U	0.95	1.1	7.3
72R	0.3 HC	2	3.1	88.3	5.20	U	1.0	1.3	8.2
74	0.3 HC	2	3.1	27.1	1.55	U	0.0	0.3	1.1
74R	0.3 HC	2	3.0	32.0	1.92	U	1.0	3.3	9.6
73	0.3 HC	3	2.9	27.0	1.12	U+100	0.5	2.2	3.0
73R	0.3 HC	3	3.1	33.8	1.30	U+100	3.6	2.7	5.1

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TABLE 94. (Continued)

Test no.	Wave	Tow speed knots	Slick thk. mm	Discharge rate m^3/hr	Pump ratio	Device position	ORR m^3/hr	RE %	TE %
69R1	Calm	3	3.0	53.6	2.15	U+100	4.4	8.3	49.8
75	Calm	4	2.9	63.2	1.93	U+100	6.0	9.5	25.6
75R	Calm	4	3.1	70.1	2.04	U+100	3.9	5.6	31.6
75A	Calm	4	3.0	68.8	2.03	U+100	3.4	5.1	11.2
68A1	Calm	2	3.1	25.4	1.48	U+100	8.4	33.3	83.2
66R1	0.3 HC	3	2.9	84.5	3.44	U+100	0.4	0.5	3.9
76	0.3 HC	2	3.1	101.4	5.80	U	0.3	0.4	3.8

*0.6 R = 0.6 m Reg
0.3 R = 0.3 m Reg
0.6 HC = 0.6 m Harbor Chop
0.3 HC = 0.3 m Harbor Chop

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TABLE 95. CYCLONET 100 MAXIMUM OBSERVED PERFORMANCE DATA CALM WATER (JO 34)

Tow speed knots	ORR m^3/hr	RE %	TE %	Oil type
2	7.1	19.4	56.8	Medium
3	9.0	20.3	54.2	Medium
4	7.1	20.0	24.1	Medium
5	5.5	7.6	19.5	Medium
6	1.3	1.5	15.9	Medium
1	3.0	15.2	64.4	Heavy
2	9.7	33.3	83.2	Heavy
3	15.4	31.0	78.5	Heavy
3.5	12.5	20.8	60.2	Heavy
4	8.4	15.5	36.7	Heavy
5	0.5	0.7	1.3	Heavy
6	0.1	0.1	2.3	Heavy

TABLE 96. CYCLONET 100 SETTINGS FOR MAXIMUM TE - CALM WATER (JO 34)

Tow speed knots	Position	Discharge rate*	Oil type
2	U+100	2.22D	Medium
3	U+100	1.74D	Medium
4	U+100	2.11D	Medium
5	U+100	1.66D	Medium
6	U	1.21D	Medium
1	U+100	2.05D	Heavy
2	U+100	1.94D	Heavy
3	U+100	2.20D	Heavy
3.5		2.10D	Heavy
4	U+100	1.85D	Heavy
5		1.84D	Heavy
6		1.27D	Heavy

*Discharge rate is referred to in terms of oil distribution rate (D).

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TABLE 97. CYCLONET 100 SETTINGS FOR MAXIMUM RE - CALM WATER (JO 34)

Tow speed knots	Position	Discharge rate*	Oil type
2	U+100	2.22D	Medium
3	U+100	1.74D	Medium
4	U+195	0.20D	Medium
5	U+100	1.66D	Medium
6	U+195	1.60D	Medium
1	U+100	2.05D	Heavy
2	U+100	1.94D	Heavy
3	U+100	1.91D	Heavy
3.5	U+100	1.97D	Heavy
4		1.65D	Heavy
5		1.84D	Heavy
6	U+100	1.14	Heavy

*Discharge rate is referred to in terms of oil distribution rate (D).

TABLE 98. CYCLONET 100 SETTINGS FOR MAXIMUM ORR - CALM WATER (JO 34)

Tow speed knots	Position	Discharge rate*	Oil type
2	U+100	2.22D	Medium
3	U+100	1.74D	Medium
4	U+100	1.07D	Medium
5	U+100	1.66D	Medium
6	U+195	1.60D	Medium
1	U+100	2.05D	Heavy
2	U+100	1.94D	Heavy
3	U+100	1.91D	Heavy
3.5	U+100	2.13D	Heavy
4	U+100	1.72D	Heavy
5		1.84D	Heavy
6	U+100	1.14D	Heavy

*Discharge rate is referred to in terms of oil distribution rate (D).

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Conclusions

Cyclonet 100

The results of testing the performance of the Cyclonet 100 at selected tow speeds in calm water indicate that the device has a recovery efficiency of less than half of the throughput efficiency. Regular waves and confused sea simulations caused all the efficiencies to drop off significantly from those achieved at identical speeds in calm water. Other conclusions derived from testing the Cyclonet 100 follow:

1. Collection performance was more successful for heavy oil than for medium viscosity oil.
2. Cyclonet performance was affected by variations greater than 16 cm from the optimum immersion depth.
3. The ratios of the pump discharge rate to oil distribution rate did not significantly alter the performance output.
4. The device, as deployed in OHMSETT, was trouble free during the six week immersion. Pump seals and system components did not require replacement or repair.
5. The mid-range of tow speeds selected for testing oil recovery proved to be the optimum for performance.

The performance of the device may have been hampered by the following conditions which should be investigated further:

1. presence of channel iron frame work around the inlet
2. formation of vortex in the mouth
3. absence of debris grill
4. inefficient performance of the hydroejector
5. high speed pump settings
6. vector relation of device with wave position (roll)
7. short steady-state time in relation to oil volume capacity in cyclone
8. steepness ratio selections
9. sensitivity of cyclone to oil properties
10. device orientation to wave direction

The effects of these conditions on the performance of the Cyclonet 100 can be studied in future tests. In addition, the normal deployment of the device (mounted in pairs on a large work boat) may require more study in future simulations at OHMSETT.

MARCO Class V Oil Skimmer

Generally, the device was dependable and trouble free. For optimum performance, a proper trade-off between the speed of advance through the water and the induction pump pressure setting was necessary; too high an induction pump setting for any given speed produced oil losses from the impeller, while too low a setting allowed more oil loss at the skimmer inlet area due to headwave shedding. The optimum vessel-speed/pump-pressure combinations were as follows:

Forward Speed:	knots	.5	1	1.5	2
Induction Pump Pressure Setting:	kg/cm^2	7.1	14.1	56.3	70.4

The best overall performance was obtained at a tow speed of 1 knot. At a forward speed of 3 knots oil recovery was so minimal that operation was impractical. Subsequent changes in pump setting and belt speed at that tow speed did not improve performance significantly.

The belt speed reflecting best performance results was 1.2 knots. Slower speeds produced a decline in recovery rate and faster speeds contributed to losses from the underside of the belt on its return to the oil slick. Oil was lost from the belt as it passed over the rungs on the underside of the ramp (this loss was observed to be directly related to belt speed).

The device performed almost as well in the medium oil as in the heavy oil. The lower viscosity of the medium oil allowed it to be drawn through the sponge belt more easily than the heavy oil. Subsequently, more medium oil was lost from the belt.

The device was successfully operated in 0.6 m and 1.2 m harbor chop wave conditions. To ensure that the belt encountered oil in these waves, a high induction pump setting was used. The device performed better in waves than in calm water when using medium oil, while performance decreased slightly with heavy oil. The performance of the device in waves varied to a great degree. The changes in test parameters were not solely responsible for these variances. Random waves sloshing oil onto the belt were probably contributing factors. However, further tests will be necessary to quantify this observation.

The polyurethane belt, normally used on the device, was subject to deterioration by sunlight. The sponge fibers became brittle and broke, thus forming larger sponge pores. As a result, the oil retention capability of the belt declined drastically. Raising the belt from the water and covering it with light canvas during inactive weekends did not sufficiently protect the sponge fibers. Over the long July 4th weekend, the first belt deteriorated over 60% of its length. Varying device settings had almost no effect on the performance of the device when using the damaged belt. The best results with the deteriorated belt were obtained using a high (102 kg/cm^2) induction pump setting and a belt speed of 2 knots. The roller squeeze pressure was

TABLE 99. TEST RESULTS MARCO CLASS V OIL SKIMMER WITH CIRCO HEAVY FIRST BELT, FIRST TEST PROCEDURE (JO 34)

List no.	Test no.	Wave	Tow speed knots	Slick thk. mm	Induction pump kg/cm^2	Belt speed knots	ORR m^3/hr	RE %	TE %
1	4	Calm	1	3.0	56.2	1.8	1.14	81.0	24.4
2	4R	Calm	1	3.0	56.2	1.8	5.27	68.2	57.9
3	4R2	Calm	1	3.0	56.2	1.8	6.50	75.4	71.0
4	4A	Calm	1	3.4	56.2	1.8	7.22	87.3	71.0
5	4A2	Calm	1	3.0	56.2	1.8	5.72	84.5	63.1
6	5	Calm	1	3.3	14.1	1.8	7.93	82.7	79.3
7	5R	Calm	1	2.8	14.1	1.8	7.99	76.4	94.9
8	5A	Calm	1	3.1	14.1	1.8	7.74	86.6	84.1
9	5A2	Calm	1	3.0	14.1	1.8	6.88	80.1	75.8
10	5B	Calm	1	2.9	14.1	1.8	7.15	62.0	83.1
11	5B2	Calm	1	2.9	14.1	1.8	7.40	60.0	85.2
12	6	Calm	1	3.1	14.1	2.4	7.84	82.7	82.8
13	6R	Calm	1	3.1	14.1	2.4	7.86	76.9	83.8
14	8	Calm	2	2.8	14.1	2	8.34	65.8	48.8
15	9	Calm	2	3.0	14.1-21.1	2	5.61	73.0	30.7
16	12	Calm	2	2.9	101.9	4.7	5.22	29.9	29.5
17	12R	Calm	2	2.9	101.9	4.7	4.09	43.1	23.2
18	13	Calm	2	3.0	101.9	4.7	8.68	76.7	47.4
19	13R	Calm	2	3.1	101.9	4.7	8.68	79.9	46.7

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TABLE 100. TEST RESULTS MARCO CLASS V OIL SKIMMER WITH CIRCO HEAVY FIRST BELT, SECOND TEST PROCEDURE (JO 34)

List no.	Test no.	Wave	Tow speed knots	Slick thk. mm	Induction pump kg/cm^2	Belt speed knots	ORR m^3/hr	RE %	TE %
20	28	Calm	.5	3.9	7.0	.4	3.00	87.1	74.3
21	29	Calm	.5	3.7	17.6	.4	NA	89.6	52.0
22	5C	Calm	1	2.8	14.1	1.8	6.88	77.3	81.3
23	5C2	Calm	1	2.8	14.1	1.8	6.88	78.1	81.3
24	5T	Calm	1	3.0	14.1	1.8	5.43	83.7	69.9
25	5T2	Calm	1	2.9	14.1	1.8	4.75	80.9	66.8
26	25	Calm	1	3.0	28.2	1.8	4.91	86.2	61.6
27	25R	Calm	1	3.0	28.2	1.8	5.47	86.1	71.1
28	26	Calm	1	3.0	42.2	1.8	4.07	88.8	53.3
29	27	Calm	1	3.1	56.2	1.8	4.57	85.6	58.8
30	27R	Calm	1	2.9	56.2	1.8	3.63	79.2	51.3
31	36	Calm	1	6.0	56.2	1.8	9.94	84.2	71.3
32	30	Calm	1.5	2.8	42.2	1.8	6.81	89.3	65.1
33	31	Calm	1.5	3.0	56.2	1.8	7.31	85.7	65.5
34	38	Calm	1.5	3.1	56.2	1.8	NA	83.0	72.8
35	32	Calm	1.5	2.9	70.3	1.8	7.34	85.6	66.2
36	33	Calm	1.5	2.9	84.4	1.8	7.09	88.4	64.1
37	34	Calm	1.5	2.9	56.2	1.2	8.52	93.4	76.6
38	35	Calm	1.5	5.8	56.2	1.8	16.15	87.5	69.2
39	17	Calm	2	2.9	42.2	2	10.36	87.9	66.8
40	17R	Calm	2	2.9	42.2	2	10.08	83.2	65.7
41	14	Calm	2	3.0	56.2	2	9.58	79.1	53.3
42	14R	Calm	2	3.1	56.2	2	8.34	77.4	50.7
43	14A	Calm	2	3.0	56.2	2	5.84	84.1	35.6
44	14A4	Calm	2	2.9	56.2	2	6.02	81.9	39.7
45	14A2	Calm	2	2.9	56.2	2	7.99	80.7	54.0
46	14A3	Calm	2	2.9	56.2	2	7.61	83.9	50.1

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TABLE 100. (Continued)

List no.	Test no.	Wave	Tow speed knots	Slick thk. mm	Induction pump kg/cm^2	Belt speed knots	ORR m^3/hr	RE %	TE %
47	18	Calm	2	3.0	56.2	1.2	12.01	92.7	72.8
48	18R	Calm	2	3.0	56.2	1.2	11.38	92.7	70.2
49	18R1	Calm	2	3.0	56.2	1.2	11.67	91.4	72.0
50	15	Calm	2	3.0	70.3	2	9.77	89.3	62.5
51	15R	Calm	2	3.1	70.3	2	10.17	83.3	61.8
52	16	Calm	2	3.0	84.4	2	9.40	89.1	61.6
53	16R	CAlm	2	2.9	84.4	2	9.24	88.3	60.7
54	24	Calm	2	2.9	84.4	1.2	10.81	93.9	68.5
55	24R	Calm	2	3.0	84.4	1.2	NA	94.3	64.0
56	19	Calm	2	2.9	98.5	2	9.97	89.7	66.3
57	19R	Calm	2	3.0	98.5	2	10.42	87.3	67.0
58	19R1	Calm	2	3.0	98.5	2	9.02	85.0	58.3
59	19R2	Calm	2	3.0	98.5	2	8.38	87.3	59.4
60	37	Calm	2	5.9	84.4	2	18.58	85.9	61.2
61	20	Calm	3	3.0	56.2	2	6.72	78.3	27.7
62	20R	Calm	3	3.1	56.2	2	5.66	84.6	21.8
63	21	Calm	3	3.0	70.3	2	3.72	74.3	14.4
64	21R	Calm	3	3.1	70.3	2	7.99	60.7	29.6
65	22	Calm	3	2.9	84.4	2	5.59	65.4	23.8
66	22R	Calm	3	2.9	84.4	2	7.22	67.3	28.4
67	23	Calm	3	2.9	98.5	2	6.11	71.0	25.2
68	23R	Calm	3	3.0	98.5	2	6.20	72.5	23.7

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TABLE 101. TEST RESULTS MARCO CLASS V OIL SKIMMER WITH CIRCO HEAVY SECOND BELT, SECOND TEST PROCEDURE (JO 34)

List no.	Test no.	Wave	Tow speed knots	Slick thk. mm	Induction pump kg/cm^2	Belt speed knots	ORR m^3/hr	RE %	TE %
69	16A	Calm	2	3.1	84.4	2	4.97	78.7	32.7
70	16B	Calm	2	3.1	84.4	2	5.13	83.1	33.0
71	16C	Calm	2	3.1	84.4	2	5.27	84.4	33.7
72	15A	Calm	2	2.9	70.3	2	5.66	84.0	38.4
73	15B	Calm	2	3.0	70.3	2	5.13	86.6	33.4
74	92	0.6 HC*	1	3.0	98.5	1.8	2.04	66.6	27.9
75	93	0.6 HC	1	3.1	70.3	1.2	2.25	43.4	29.8
76	94	0.6 HC	1.5	2.9	56.2	1.8	3.70	49.0	31.2
77	95	0.6 HC	2	5.7	52.7	1.8	4.00	47.8	13.9
78	95R	0.6 HC	2	5.8	52.7	1.8	4.47	41.6	14.8
79	96	1.2 HC*	1	3.1	70.3	1.8	2.59	48.3	33.5
80	97	1.2 HC	1	3.0	98.5	1.8	2.13	44.2	28.3
81	98	1.2 HC	1.5	2.8	70.3	1.8	3.27	47.4	28.6
82	90	0.6 HC	1	3.0	42.3	1.8	4.36	47.7	61.9
83	90R	0.6 HC	1	3.1	42.3	1.8	4.77	47.4	63.0
84	91	0.6 HC	1	3.0	70.3	1.8	4.04	46.5	55.0

*0.6 HC = 0.6 m Harbor Chop
1.2 HC = 1.2 m Harbor Chop

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TABLE 102. TEST RESULTS MARCO CLASS V OIL SKIMMER WITH CIRCO MEDIUM FIRST BELT, SECOND TEST PROCEDURE (JO 34)

List no.	Test no.	Wave	Tow speed knots	Slick thk. mm	Induction pump kg/cm^2	Belt speed knots	ORR m^3/hr	RE %	TE %
85	40	Calm	1	3.5	14.1	1.8	6.61	75.2	79.2
86	40R	Calm	1	3.3	14.1	1.8	5.84	71.8	70.8
87	41	Calm	1	3.6	28.2	1.8	6.63	68.8	74.0
88	41R	Calm	1	3.2	28.2	1.8	5.61	60.9	75.0
89	42	Calm	1	2.9	42.3	1.8	4.32	52.2	67.4
90	43	Calm	1	2.9	56.2	1.8	NA	51.1	63.5
91	44R	Calm	1	3.0	42.3	1.2	4.09	59.5	54.9

TABLE 103. TEST RESULTS MARCO CLASS V OIL SKIMMER WITH CIRCO MEDIUM FIRST BELT, THIRD TEST PROCEDURE (JO 34)

List no.	Test no.	Wave	Tow speed knots	Slick thk. mm	Induction pump kg/cm^2	Belt speed knots	ORR m^3/hr	RE %	TE %
92	45	Calm	1	3.1	14.1	1.8	5.79	50.5	57.7
93	46	Calm	1	3.1	28.3	1.8	6.70	59.5	67.0
94	47	Calm	1	3.0	42.3	1.8	6.50	58.9	65.0

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TABLE 104. TEST RESULTS MARCO CLASS V OIL SKIMMER WITH CIRCO MEDIUM SECOND BELT, THIRD TEST PROCEDURE (JO 34)

List no.	Test no.	Wave	Tow speed knots	Slick thk. mm	Induction pump kg/cm^2	Belt speed knots	ORR m^3/hr	RE. %	TE. %
95	48A	Calm	2	3.2	56.2	1.8	5.41	78.2	29.8
96	48B	Calm	2	3.0	56.2	1.8	9.31	60.0	48.4
97	48C	Calm	2	3.0	56.2	1.8	10.20	68.6	50.5
98	49A	Calm	2	3.0	70.3	1.8	12.47	72.2	58.1

TABLE 105. TEST RESULTS MARCO CLASS V OIL SKIMMER WITH CIRCO MEDIUM SECOND BELT, SECOND TEST PROCEDURE (JO 34)

List no.	Test no.	Wave	Tow speed knots	Slick thk. mm	Induction pump kg/cm^2	Belt speed knots	ORR m^3/hr	RE %	TE %
99	52A	Calm	2	3.0	42.3	1.8	5.18	47.6	35.4
100	51A	Calm	2	3.0	56.2	1.8	8.13	57.3	53.0
101	50A	Calm	2	3.1	70.3	1.8	7.47	55.3	48.1
102	53A	Calm	2	3.0	84.4	1.8	5.63	69.0	36.8
103	54A	Calm	2	3.0	84.4	2	5.75	82.2	38.4
104	55A	Calm	2	6.2	84.4	2	15.10	86.0	50.2
105	80	1.2 HC*	1	3.7	42.3	1.8	7.20	29.1	84.8
106	80R	1.2 HC	1	3.9	42.8	1.8	3.86	38.2	39.7
107	81	1.2 HC	1	4.2	70.3	1.8	3.75	51.5	35.8
108	82	1.2 HC	1	3.0	98.5	1.8	4.57	29.4	63.7
109	83	1.2 HC	1.5	3.0	56.2	1.8	8.27	30.0	68.8

*1.2 HC = 1.2 m Harbor Chop

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TABLE 106. TEST RESULTS MARCO CLASS V OIL SKIMMER WITH CIRCO MEDIUM DETERIORATED BELT, SECOND TEST PROCEDURE (JO 34)

List no.	Test no.	Wave	Tow speed knots	Slick thk. mm	Induction pump kg/cm^2	Belt speed knots	ORR m^3/hr	RE %	TE %
110	57	Calm	1	6.0	56.2	1.8	4.43	72.1	28.3
111	58	Calm	1	8.9	56.2	1.8	6.22	79.4	30.2
112	58A	Calm	1	8.8	56.2	1.8	5.93	86.8	29.5
113	62	Calm	1.5	3.0	28.2	1.8	3.54	63.8	28.7
114	62R	Calm	1.5	3.0	28.2	1.8	2.86	65.1	37.0
115	61	Calm	1.5	3.3	42.3	1.8	4.81	73.2	37.0
116	61R	Calm	1.5	3.0	42.3	1.8	3.72	78.1	31.6
117	56	Calm	1.5	6.0	56.2	1.8	6.59	81.5	30.6
118	59	Calm	1.5	8.6	56.2	1.8	NA	87.3	26.8
119	65	Calm	2	3.1	28.2	1.8	5.11	63.0	32.2
120	52	Calm	2	3.1	42.3	1.8	3.43	71.6	20.2
121	52R	Calm	2	3.0	42.3	1.8	3.86	63.4	24.7
122	48	Calm	2	3.0	56.2	1.8	4.63	76.3	23.3
123	50	Calm	2	3.0	56.2	1.8	3.54	70.1	22.1
124	49	Calm	2	3.0	70.3	1.8	4.68	72.7	23.9
125	51	Calm	2	3.0	70.3	1.8	3.88	72.8	25.4
126	64	Calm	2	3.1	28.2	.6	4.29	63.0	23.5
127	63	Calm	2	3.0	42.3	.6	6.13	78.7	30.3
128	63R	Calm	2	3.0	42.3	.6	4.52	69.6	26.4
129	53	Calm	2	3.1	84.4	1.8	4.00	80.3	25.0
130	53R	Calm	2	3.1	84.4	1.8	4.32	81.3	26.7
131	54	Calm	2	2.9	84.4	2	4.81	75.9	31.2
132	54R	Calm	2	3.0	84.4	2	5.54	77.4	34.5
133	55	Calm	2	6.0	84.4	2	8.11	83.7	26.5

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TABLE 106. (Continued) (JO 34)

List no.	Test no.	Wave	Tow speed knots	Slick thk. mm	Induction pump kg/cm^2	Belt speed knots	ORR m^3/hr	RE %	TE %
134	55R	Calm	2	6.1	84.4	2	7.97	77.3	25.6
135	60	Calm	2	8.7	84.4	2	NA	87.0	26.6
136	71	0.6 HC*	1	3.0	28.2	1.8	3.75	39.4	47.3
137	72	0.6 HC	1	3.2	42.3	1.8	2.93	65.4	36.8
138	70	0.6 HC	1	3.6	56.2	1.8	4.29	49.7	48.5
139	73	0.6 HC	1	2.9	70.3	1.8	NA	70.4	NA

*0.6 HC = 0.6 m Harbor Chop

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TABLE 107. MARCO CLASS V OIL SKIMMER MAXIMUM PERFORMANCE DATA FOR CALM WATER - 3 mm THICK SLICK (JO 34)

Tow speed knots	ORR m^3/hr	RE %	TE %	Oil type
.5	3.0	89.6	74.3	Heavy
1	8.0	88.8	94.9	Heavy
1.5	8.5	93.4	76.6	Heavy
2	12.0	94.3	72.8	Heavy
3	8.0	84.6	29.6	Heavy
1	6.7	75.2	79.2	Medium
2	12.5	82.2	58.1	Medium

TABLE 108. MARCO CLASS V OIL SKIMMER MAXIMUM PERFORMANCE DATA FOR CALM WATER - 6 mm THICK SLICK (JO 34)

Tow speed knots	ORR m^3/hr	RE %	TE %	Oil type
1	10.0	84.2	71.3	Heavy
1.5	16.2	87.5	69.2	Heavy
2	18.6	85.9	61.2	Heavy
2	15.1	86.0	50.2	Medium

TABLE 109. MARCO CLASS V OIL SKIMMER SETTINGS FOR MAXIMUM TE IN CALM WATER - 3 mm THICK SLICK (JO 34)

Tow speed knots	Induction pump settings kg/cm^2	Belt speed knots	Oil type
.5	7.0	0.3	Heavy
1	14.1	1.8	Heavy
1.5	56.3	1.2	Heavy
2	56.2	1.2	Heavy
3	70.2	2	Heavy
1	14.1	1.8	Medium
2	70.2	1.8	Medium

TABLE 110. MARCO CLASS V OIL SKIMMER SETTINGS FOR MAXIMUM TE IN CALM WATER - 6 mm THICK SLICK (JO 34)

Tow speed knots	Induction pump settings kg/cm^2	Belt speed knots	Oil type
1	56.3	1.8	Heavy
1.5	56.3	1.8	Heavy
2	84.3	2	Heavy
2	84.3	2	Medium

TABLE 111. MARCO CLASS V OIL SKIMMER SETTINGS FOR MAXIMUM RE IN CALM WATER - 3 mm THICK SLICK (JO 34)

Tow speed knots	Induction pump settings kg/cm^2	Belt speed knots	Oil type
.5	17.5	.3	Heavy
1	42.2	1.8	Heavy
1.5	5.3	1.2	Heavy
2	84.3	1.2	Heavy
3	56.3	2	Heavy
1	56.3	1.8	Medium
2	84.3	2	Medium

TABLE 112. MARCO CLASS V OIL SKIMMER SETTINGS FOR MAXIMUM RE IN CALM WATER - 6 mm THICK SLICK (JO 34)

Tow speed knots	Induction pump settings kg/cm^2	Belt speed knots	Oil type
1	56.3	1.8	Heavy
1.5	56.3	1.8	Heavy
2	84.3	2	Heavy
2	84.3	2	Medium

TABLE 113. MARCO CLASS V OIL SKIMMER SETTINGS FOR MAXIMUM ORR IN CALM WATER - 3 mm THICK SLICK (JO 34)

Tow speed knots	Induction pump settings kg/cm^2	Belt speed knots	Oil type
.5	7.0	.3	Heavy
1	14.1	1.8	Heavy
1.5	56.2	1.2	Heavy
2	56.2	1.8	Heavy
3	70.2	2	Heavy
1	28.1	1.8	Medium
2	70.2	1.8	Medium

TABLE 114. MARCO CLASS V OIL SKIMMER SETTINGS FOR MAXIMUM ORR IN CALM WATER - 6 mm THICK SLICK (JO 34)

Tow speed knots	Induction pump settings kg/cm^2	Belt speed knots	Oil type
1	56.3	1.8	Heavy
1.5	56.3	1.8	Heavy
2	84.3	2	Heavy
2	84.3	2	Medium

not varied from the 2.46 kg/cm^2 recommended in the operations manual. The deteriorated belt was replaced with a new belt which had accompanied the device. It had been slightly oiled and wrapped in black polyethylene. Up until the time of its use, it was stored away from sunlight.

The second belt did not perform as well as the first one prior to its deterioration. In comparison tests using the same parameters, discrepancies in throughput efficiency of as much as 45% were recorded. The second belt appeared in good shape with the sponge fibers flexible and the sponge pores of a size comparable to the ones in the first belt when it was new. The cause for the difference in performance has not yet been determined.

When new, both sorbent belts required at least one oil run to pre-wet them before consistent results could be obtained. After a test run, a good deal of oil remained in the belt or beneath the belt ramp. This contributed to a decline in throughput efficiency from 52% to 44% reflecting a retained volume of approximately 26 litres. The belt probably could not retain 24 kg of oil after squeezing, so it is reasonable to say that most of this oil was located beneath the belt and between the forward hulls. To recover some of this oil, the belt was run after the test until very little oil resulted from the squeezing process. Some oil probably remained beneath the belt, between the hulls. In future testing, this volume should be considered when determining throughput efficiency.

The water drawn through the sponge belt by the induction pump caused oil loss from the belt as it was returning to contact the slick. To see if a current could be induced beneath the belt to subsequently draw oil to it without passing a great deal of water through the sponge in the process, the belt ramp was raised until only a small portion remained in the water. However, performance declined using this method.

Running the device without using the debris scraper did not affect performance.

The floating guide ropes, located within the boom adapters and the device collection area, appeared to prevent oil from spreading out to the billowing boom adapters. This was advantageous since small vortices developed there which tended to cause oil loss beneath the contact zone of the device.

A relatively stagnant region developed in the throat of the device (0.6 m forward of the sorbent belt) in almost every test. This allowed oil to build and thus escape by headwave shedding or by entering the vortices generated in the boom adapters. The results of the three test procedures indicate device performance would increase if this stagnant area was eliminated. Water or air jets in the bows or the boom adapters should be investigated as a possible solution.

U.S. Coast Guard Skimming Barrier

The results of performance testing the Coast Guard Skimming Barrier in combination with their high seas skimmer indicate that the system produces high recovery efficiencies and oil recovery rates at the normal low speed current simulations in calm water and wave conditions.

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TABLE 115. TEST RESULTS COAST GUARD SKIMMING BARRIER WITH CIRCO HEAVY OIL (JO 34)

Test no.	Wave	Tow speed knots	Engine speed rpm	Hydraulic pressure kg/cm^2	Hydraulic flow rate m^3/hr	Total sample collected. m^3	RE %	ORR m^3/hr
1	Calm	.5	1500	80.9	2.84	STABILITY		
2	Calm	.75	1500	78.9	2.84	STABILITY		
3	Calm	1	2200	104.1	4.26	STABILITY		
4	Calm	1.25	2200	77.3	4.32	STABILITY		
4R	Calm	1.25	2000	98.4	3.86	STABILITY		
5	Calm	1.5	2000	99.8	3.86	STABILITY		
6	Calm	.5	1500	88.6	2.73	1.85	64.1	71.2
7	Calm	.75	1500	106.9	2.66	1.77	82.5	87.6
7R	Cal	.75	1500	102.7	2.68	1.80	81.0	87.4
8	Calm	1	2000	136.4	3.82	2.38	75.5	108.2
8R	Calm	1	2000	142.0	3.75	2.30	72.3	99.9
9	Calm	1.25	2000	115.3	3.86	2.32	75.7	104.0
10	Calm	.9	2000	113.9	3.79	2.54	69.3	105.4
11	Calm	1	2400	125.2	4.57	2.61	64.6	100.5
14	0.3 R*	.9	2000	111.1	3.84	2.37	74.0	105.4
14R	0.3 R	.9	2000	111.1	3.84	2.47	68.1	101.0
6R	Calm	.5	1500	97.0	2.84	2.00	65.8	78.9
6A	Calm	.5	1000	84.0	1.82	0.94	65.2	36.8
12	0.3 R	1	2000	118.1	3.68	2.87	63.5	110.1
13	0.3 R	.5	1500	87.2	2.88	2.06	50.6	63.0
13A	0.3 R	.5	2000	102.7	3.86	2.69	47.9	80.0
15	0.5 R	.9	2000	105.5	3.86	2.67	58.1	93.5
15A	0.5 R	.5	2000	105.5	3.95	2.77	48.5	80.8
15R	0.5 R	.9	2000	105.5	3.86	2.66	59.1	95.0
17	0.3 HC*	.5	2000	94.2	3.82	2.62	50.1	79.0
17R	0.3 HC	.5	2050	101.2	3.86	2.76	42.6	70.6

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TABLE 115. (Continued)

Test no.	Wave	Tow speed knots	Engine speed rpm	Hydraulic pressure kg/cm^2	Hydraulic flow rate m^3/hr	Total sample collected m^3	RE %	ORR m^3/hr
17A	0.3 HC	.9	2000	139.2	3.63	2.45	63.3	92.7
17AR	0.3 HC	.9	2050	143.4	3.75	2.39	63.5	90.9
18	Calm	.5	2000	77.3	3.63	6.01	59.3	58.8
18A	Calm	.75	1900	149.1	3.63	6.05	70.0	76.2
18B	Calm	.75	1900	143.4	3.63	6.09	70.0	77.6
18C	Calm	.75	2000	108.3	3.86	6.26	60.2	72.9
18D	Calm	.75	2000	105.5	3.86	6.05	58.7	81.8

*0.3 R = 0.3 m Regular Wave
0.3 HC = 0.3 m Harbor Chop

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TABLE 116. TEST RESULTS COAST GUARD SKIMMING BARRIER WITH CIRCO MEDIUM OIL (JO 34)

Test no.	Wave	Tow speed knots	Engine speed rpm	Hydraulic pressure kg/cm^2	Hydraulic flow rate m^3/hr	Total sample collected m^3	RE %	ORR m^3/hr
26	Calm	.5	1500	80.9	2.73	0.99	63.2	37.4
26R	Calm	.5	1500	83.0	2.84	1.90	59.4	67.9
27	Calm	.75	1500	94.9	2.73	1.66	80.0	79.5
27R	Calm	.75	1500	97.0	2.84	1.67	67.0	67.1
28	Calm	1	2000	124.4	3.86	2.20	60.5	80.0
28R	Calm	1	2000	123.7	3.75	2.29	60.0	82.5
31	Calm	1	2400	130.8	4.54	2.72	59.9	97.9
30	Calm	.9	2000	125.2	3.75	2.40	54.5	78.1
29	Calm	1.25	2000	101.2	3.86	2.40	52.3	75.3
37	0.3 HC*	.5	2000	90.0	3.75	2.49	28.3	42.6
37R	0.3 HC	.5	2000	88.6	3.75	2.63	26.8	42.0
37A	0.3 HC	.9	2000	97.0	3.75	2.53	40.4	61.2
37AR	0.3 HC	.9	2000	90.7	3.86	2.5	39.3	60.0
33A	0.3 HC	.5	2000	91.4	3.86	2.66	37.7	60.3
33AR	0.3 HC	.5	2000	60.5	3.86	1.21	38.4	24.1
33AR'	0.3 HC	.5	2000	94.2	3.86	2.75	41.4	68.3
34	0.3 HC	.9	2000	125.9	3.75	2.41	56.8	81.8
34R	0.3 HC	.9	2000	135.7	3.75	2.37	59.0	83.9
38	Calm	.5	2000	97.7	3.75	2.57	45.5	69.4
39	Calm	.9	2000	135.7	3.63	2.17	49.0	63.0
40	0.3 R	.75	2000	135.7	3.86	2.53	48.0	73.1
32	0.3 R	1	2000	117.4	3.75	2.36	39.1	54.1
35A	0.5 R	.5	2000	96.3	3.86	2.71	31.3	50.6
35	0.5 R	.9	2000	100.5	3.75	2.73	35.3	57.9

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TABLE 116. (Continued)

Test no.	Wave	Tow speed knots	Engine speed rpm	Hydraulic pressure kg/cm^2	Hydraulic flow rate m^3/hr	Total sample collected m^3	RE %	ORR m^3/hr
35R	0.5 R	.9	2000	111.1	3.75	2.62	50.6	79.7
41	0.6 HC	.75	2000	100.5	3.86	2.82	42.4	71.5
42	0.6 HC	1	2000	104.8	3.86	2.60	35.5	54.6
43	0.6 HC	.5	2000	92.8	3.75	2.55	30.2	46.2
43R	0.6 HC	.5	2000	92.1	3.86	2.60	25.8	39.8
44	0.6 HC	.9	2000	92.1	3.86	2.69	31.9	51.5
44R	0.6 HC	.9	2000	87.2	3.75	2.62	29.7	46.6
45	0.6 HC	1	2000	87.9	3.75	2.62	29.7	47.2
46	0.6 HC	.75	2000	90.0	3.86	2.68	33.3	53.6
46R	0.6 HC	.75	2000	86.5	3.86	2.65	36.6	57.9
34R'	0.5 R	.9	2000	87.9	3.75	2.59	44.7	69.9
42R	0.5 R	1	2000	89.3	3.86	2.77	37.1	57.8

*0.3 HC = 0.3 m Harbor Chop
0.3 R = 0.3 m Regular Wave
0.5 R = 0.5 m Regular Wave
0.6 HC = 0.6 m Harbor Chop

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TABLE 117. COAST GUARD SKIMMING BARRIER MAXIMUM PERFORMANCE DATA FOR CALM WATER (JO 34)

Tow speed knots	ORR m^3/hr	RE %	Oil type
0.5	78.9	65.8	Heavy
0.75	87.6	82.5	Heavy
0.9	105.5	69.3	Heavy
1.0	108.2	75.5	Heavy
1.25	104.0	75.7	Heavy
0.5	69.4	63.2	Medium
0.75	79.5	80.0	Medium
0.9	78.1	54.5	Medium
1.0	97.9	60.5	Medium
1.25	75.3	52.3	Medium

TABLE 118. COAST GUARD SKIMMING BARRIER SETTINGS FOR MAXIMUM ORR IN CALM WATER (JO 34)

Tow speed knots	Engine speed rpm	Hydraulic pressure kg/cm^2	Oil type
0.5	1500	96.9	Heavy
0.75	1500	106.8	Heavy
0.9	2000	114.9	Heavy
1.0	2000	136.4	Heavy
1.25	2000	115.3	Heavy
0.5	2000	96.7	Medium
0.75	1500	94.9	Medium
0.9	2000	125.1	Medium
1.0	2400	135.7	Medium
1.25	2000	101.2	Medium

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TABLE 119. COAST GUARD SKIMMING BARRIER DEVICE SETTINGS FOR MAXIMUM RE IN CALM WATER (JO 34)

Tow speed knots	Engine speed rpm	Hydraulic pressure kg/cm^2	Oil type
0.5	1500	96.9	Heavy
0.75	1500	102.7	Heavy
0.9	2000	113.9	Heavy
1.0	2000	136.4	Heavy
1.25	2000	115.3	Heavy
0.5	1500	80.0	Medium
0.75	1500	94.9	Medium
0.9	2000	125.1	Medium
1.0	2000	124.4	Medium
1.25	2000	101.2	Medium

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Performance decreased in waves in contrast with calm water conditions. Also, in wave conditions, recovery of medium viscosity oil decreased as opposed to heavy oil.

The device rigging was preset at the same level for all tests. The various pump rates selected did not affect performance except at extreme high and low settings.

The device operating design and test design for simulating an order of magnitude longer barrier precluded quantifying throughput efficiency performance.

The seakeeping ability of the barrier was commendable at most test conditions. There were considerable losses under the barrier at the higher tow speeds that were not attributable to the OHMSETT tank wall effects. The diaphragm pumps maintained high capacity but required various seal replacements in the pumps and a manifold-flow divider in the hydraulic fluid paths.

The device was rigged in a fixed operational position for the OHMSETT test series. It is recommended that future tests be conducted to study variables not included in this series, such as:

1. Barrier radius at apex
2. Light version of ASTM oils
3. Throughput efficiency measurements
4. Performance of individual weirs
5. Variation of current direction
6. Following sea conditions

JOB ORDER NO. 35 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 2-13 May 1977

Customer Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Devices Harbour Boom
Clean Water, Inc.
Courthouse Square
P.O. Box 1002
Toms River, NJ 08753 201-341-3600

Kaiser OELA-III Swiss Oil Skimmer
Industrial & Municipal Engineering (IME)
P.O. Box N, U.S. Route 34 East
Galva, IL 61434 309-932-2036

AFFF Fire Fighting Foam (FC-206)
3-M Company
3-M Center Building 220-7W
St. Paul, MN 55101 612-733-3906

Imbiber Beads
Dow Chemical Co., USA
2020 Dow Center
Midland, MI 48640 517-636-5075

Report: Breslin, M.K. and M.D. Royer. Sorbents and AFFF Effects on Floatable Hazardous Material Recovery. U.S. Environmental Protection Agency, Cincinnati, Ohio, 1980 (in press) (Ref. 12).

Description of Program

This EPA research program determined the effect of sorbent materials and fire fighting foam on containment, recovery, and vapors of spilled hazardous materials. The test equipment included the Clean Water, Inc. Harbour Boom, and the I.M.E. Swiss OELA III skimmer. The test fluids were dioctyl phthalate, octanol, and naphtha. Sorbents included polyurethane foam cubes, Clean Water, Inc. Sorbent-C, and Dow Chemical Imbiber Beads. An aqueous film-forming foam (AFFF) from 3-M Company was used as the fire fighting foam. Results of the tests were evaluated in terms of the critical tow speed of the boom, hazardous material vapor concentration, and recovery ability with and without the addition of the selected agents. An EPA report is in printing.

Conclusions

The following conclusions were drawn from the evaluation of the test data and observations of equipment performance.

The application of sorbents or congealing agents to a floating HM spill is certainly possible with a minimum amount of equipment.

The introduction of sorbents or congealing agents into HM enables a stable boom to contain the material to a higher current velocity in calm water. The velocity at which shedding occurs is directly related to the amount of congealing agent introduced and the thoroughness of interaction between it and the HM. During the Naphtha tests with foam cubes, the boom was brought up to its critical stabilization speed without shedding. A more stable boom would have contained the material beyond the 1.5 kt limit.

The sorbents and imbiber beads did not enhance containment in the presence of the 0.3 m harbor chop. The congealing agent could have been used to excess to enhance containment but clean up would have been very difficult. Such use would be costly in material and possibly damaging to the environment. Tank and equipment clean up consisted mainly of removing the oil-soaked imbiber beads from everything they touched.

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TABLE 120. IME SWISS OELA III SKIMMER RESULTS (JO 35)

Test no.	Duration of test secs.	Test fluid	Sorbent and foam	Cumulative Samples Water m^3	 Oil and solids m^3	Discrete Sample Water %	 Oil %	 Solids %	Comments
A -2S	900	Naphtha	Sorbent C	0.76	0.71	2.0	70.4	27.5	Double diaphragm pump clogged intermittently.
A -3S	300	Naphtha	Beads	0.17	0.40	11.2	88.8	N/A	Used double diaphragm pump.
A -5S	600	Naphtha	Sorbent C	0.97	0.20	6.0	64.0	30.0	Waves washed material into skim.
B -3S	180	DOP*	Beads	0.25	0.39	18.0	82.0	N/A	Rotary pump used from here on.
C -2S	180	Octanol	Sorbent C	0.18	0.55	N/A	N/A	N/A	
G -2S	240	Naphtha	Sor. C** & Foam	0.44	0.34	9.2	90.8	N/A	
G -3S	300	Naphtha	Beads & Foam	0.60	0.51	11.5	88.5	N/A	Beads very congealed.
J -2S	135	Octanol	Sor. C & Foam	0.16	0.45	3.6	79.1	17.3	
J -3S	225	Octanol	Beads & Foam	0.37	0.39	7.3	92.7	N/A	
H -2S	225	DOP	Sor. C & Foam	0.30	0.45	13.3	34.5	52.2	Sample taken from upper layer.
J -0S	330	Octanol		0.63	0.51	26.0	74.0	0	Control test.

*Dioctyl phthalate

**Sorbent C

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TABLE 121. VAPOR DETECTION TEST DATA USING NAPHTHA (JO 35)

		ABSORBANCE		CONCENTRATION (ppm)			
Test no.	Sorbent	HM	HM* and Sorbent	HM	HM and Sorbent	$C = C_{HMS\&S} - C_{HM}$ (ppm)	Comments
A-0	None	0.26	0.40	11	28	+17	Crosswind from East to West.
A-1	Cubes	Inop	0.40	N/A	28		No HM filter, no tests taken over HM. Sample inlet for HM was about 20' from apex of boom and collected slick. Boom was short for other tests.
A-1R	Cubes		NO DATA	N/A			No new sorbent broadcast.
A-2	Sorbent C		NO DATA - RECORDER MALFUNCTION				
A-3	Beads	0.30	0.37	15	24	+9	Rained during test. Boom shifted west of the HM/S sample inlet.
A-3R	Beads	0.32	0.42	18	30	+12	Slick past filter when test began. Imbiber beads already on water.
A-4			DATA NOT RECORDED				0.3 m HC.
A-5	Sorbent C	0.19	0.20	3	4	+1	Bridge speed very slow, 0.3 m HC.
A-6	Beads	0.18	0.42	2	30	+28	Each filter placed 2 ft. above calm water surface - for 0.3 m HC. Slick was at apex before test began.

*HM = hazardous materials
S = sorbent

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TABLE 122. VAPOR DETECTION TEST DATA USING NAPHTHA AND AFFF* (JO 35)

		ABSORBANCE		CONCENTRATION (ppm)			
Test no.	Sorbent	HM	HM and Sorbent	HM	HM and Sorbent	$C = C_{HMS\&S} - C_{HM}$ (ppm)	Comments
G-1	Cubes	0.32	0.24	18	9	-9	Wind blowing to South.
G-2	Sorbent C	0.22	0.30	6	15	+9	Protective cover put over filter. Wind direction to East. Slick collected on West.
G-3	Imbiber Beads	0.22	0.36	6	23	+17	Slick built up on west side of tank. Break in foam occurred.
G-3R	Imbiber Beads	N/A No new Sorb or Im. Beads	0.26		11	N/A	Irregular foam coverage of slick (patches). HM/S filters encased in aluminum pipe to stiffen PVC pipe.

*AFFF = Aqueous Film Forming Foam

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TABLE 123. VAPOR DETECTION TEST DATA USING DOP (JO 35)

		ABSORBANCE		CONCENTRATION (ppm)			
Test no.	Sorbent	HM	HM and Sorbent	HM	HM and Sorbent	$C = C_{HMS\&S} - C_{HM}$ (ppm)	Comments
B-0	None	0.20	0.20	6	6	0	More HM distributed than test plan called for.
B-1	Poly Chips	0.18	0.19	3	4	+1	Filters at 0.6 m instead of 0.3 m above water.
B-2	Sorbent C	0.23	0.58	9	59	+50	Slick moved to west side of tank. Had changed filter prior to run. Filter probably contaminated.
B-3	Beads	0.25	0.27	17	15	+3	HM/S pipe lengthened to 3.7 m. Recorder failure. Observed max. & recorded manually. Wind blowing to North. Temp.-3.3°C HM/S filter adjusted over slick.
B-4	Cubes	0.16	0.19	0	4	+4	Pump switch off during part of experiment. Boom apex did not move directly under filter.
B-5	Sorbent C	0.16	0.165	0	0.4	+0.4	Same slick from a previous run was used, therefore slick of plain HM did not pass under the HM filter-wind speed minimal at filter.

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TABLE 124. VAPOR DETECTION TEST DATA USING DOP AND AFFF (JO 35)

		ABSORBANCE		CONCENTRATION (ppm)			
Test no.	Sorbent	HM	HM and Sorbent	HM	HM and Sorbent	$C = C_{HMS\&S} - C_{HM}$ (ppm)	Comments
H-1	Poly	0.24	0.26	11	14	+3	Temperature 25.6°C.
H-2	Imbiber Beads	0.21	0.23	7	10	+3	Wind blowing lightly to North.

TABLE 125. VAPOR DETECTION TEST DATA USING OCTANOL (JO 35)

		ABSORBANCE		CONCENTRATION (ppm)			
Test no.	Sorbent	HM	HM and Sorbent	HM	HM and Sorbent	$C = C_{HMS\&S} - C_{HM}$ (ppm)	Comments
C-1	None	0.21	0.24	7	10	+3	
C-1	Poly Chips	0.22	0.22	8	8	0	Brisk wind blowing to South (generally). Cold day. Slick was well dispersed when passing first filter.
C-2	Imbiber Beads	0.18	0.20	2	6	+4	Boom shifted to west of centerline of tank.

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TABLE 126. VAPOR DETECTION TEST DATA USING OCTANOL AND AFFF (JO 35)

		ABSORBANCE		CONCENTRATION (ppm)			
Test no.	Sorbent	HM	HM and Sorbent	HM	HM and Sorbent	$C = C_{HMS\&S} - C_{HM}$ (ppm)	Comments
J-2	Beads	0.20	0.21	6	7	+1	Filter failed test - no time to change.
J-3	Sorbent C	0.22	0.24	8	14	+6	

TABLE 127. FILTER CONTROL TESTS (JO 35)

		ABSORBANCE*/ CONCENTRATION ppm	
Date and time	Hazardous material	HM	HM/Sorbent
11 May 1977 Before test runs 0815 to 0845 hours	Naphtha	0.26/11	0.32/18
11 May 1977 Following test G-1	Naphtha	0.60/51	0.54/44
Following test G-3	Naphtha	0.40/27	0.28/14
12 May 1977 Pre-test filter tests	Naphtha	0.54/44	**
After test J-3	Naphtha	0.72/64	0.74/66
After test J-3	Octanol DOP	0.26/14 0.22/8	0.22/8 0.22/8

* Absorbance is non-dimensional

**Cancelled due to HM in water below filter, might have contaminated readings.

A contact and mixing time with the HM is required for the sorbents and imbiber beads in order for them to work well. Applying the sorbent or imbiber beads to the surface of the slick as it approaches the boom does not sufficiently mix the materials.

Due to wind and the relatively low vapor pressure of octanol and DOP, results from the vapor detection portion of this test project were sketchy. Naphtha was the only HM from which readings could be obtained. Conclusions can be drawn on a large scale only. Laboratory tests should be conducted to obtain precise data.

The vapor concentration above the slick did not increase dramatically when sorbent material was applied.

The fire fighting foam showed a net positive result in suppressing the vapors above the slick.

JOB ORDER NO. 36 - U.S. COAST GUARD

Dates	8-21 August 1977	
Customer	Office of Research and Development U.S. Coast Guard G-DMT-4/TP54 Washington, D.C. 20593	202-426-1023
Device	Streaming Fibers Skimmer Seaward International, Inc. 6269 Leesburg Pike Falls Church, VA 22044	703-534-3500
Report	Beach, R.L. and D.W. Durfee. Development of a Streaming-Fiber Oil Spill Control System Stage II-Modifications to a Large-Scale Model. CG-D-07-79. U.S. Coast Guard, Washington, D.C. 1978. 82 pp (Refs. 3, 24).	

Description of Program

Three full-size prototypes of Fast-current Skimmers were evaluated for the U.S. Coast Guard. The Catamaran Hydroclone Experimental Skimmer and Separator (CHESS), Seaward International, Inc.'s Streaming Fiber Concept, and Shell Development Co.'s Zero Relative Velocity (ZRV) Belt Concept were tested over a wide range of device-specific and environmental variables. The test plan involved the determination of an optimum value for a given parameter, followed by testing variations of a second parameter while holding the first constant at its optimum value. Three oils provided a wide range of test fluid properties. An automated data acquisition system and computer analysis were used. For additional information, contact U.S. Coast Guard Headquarters, (G-DMT-4/TP54), Washington, D.C. 20593. (Also see Job Order 20)

Conclusions

A series of performance tests were conducted at the EPA's OHMSETT test facility during the periods of July 13-24 and August 12-14, 1976. This section briefly describes the test program and summarizes the important points learned from the testing.

The test results in general showed the following:

1. The concept works on a large scale parallel oriented fibers are effective in slowing down oil for recovery by conventional means, using operational size hardware.
2. Proper adjustment of a few device parameters is important for optimum performance.
3. Performance in waves was poor, apparently because the tighly strung fibers in this particular model arrangement caused excessive oil-water mixing as the vertical wave components passed through the fibers.
4. Performance falls off rapidly as the design current velocity (4.8 kts in this model) is exceeded.
5. Use of a solid belt is effective in sweeping the oil to the weir area, but was not particularly effective in reducing the deleterious effects of wave motion.
6. At higher speeds, light oils tend to be more efficiently recovered than viscous oils.

JOB ORDER NO. 37 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	31 May - 6 June 1977 20 August 1977	
Customer	U.S. Environmental Protection Agency Oil and Special Materials Control Division, OSMCD (WH-548) 401 M Street S.W. Washington, DC 20460	202-245-3045
Device	Infrared Oil Spill Detector Rambie, Inc. P.O. Box 3214 Irving, TX 75061	214-438-6909
Report	Rambie, G.S. Jr. and R.H. Morgan. Scanning Oil Sensor Tests at the OHMSETT Facility. U.S. Environmental Protection Agency, Washington, DC (in preparation) (Ref. 43).	

TABLE 128. TEST RESULTS FOR RAMBIE OIL DETECTOR (JO 37)

Test no.	X* (m)	Y* (m)	H (m)	Waves L (m)	P (secs)	Oil or water
A-1	61	64	0			water
A-2	183	64	0			water
A-3	183	64	0.8	12	3	water
A-4	61	64	0.8	12	3	water
A-5	61	64	0.4	6	1.9	water
A-6	183	64	0.4	6	1.9	water
A-7	183	64	0.15	23	5.5	water
A-8	61	64	0.15	23	5.5	water
A-9	61	64	0.6	HC		water
A-10	183	64	0.6	HC		water
A-11	183	64	1.2	HC		water
A-12	61	64	1.2	HC		water
B-1	61	15	0			water
B-2	183	15	0			water
B-3	183	15	1.2	HC		water
B-4	61	15	1.2	HC		water
B-5	61	15	0.6	HC		water
B-6	183	15	0.6	HC		water
B-7	183	15	0.15	23	5.5	water
B-8	61	15	0.15	23	5.5	water
B-9	61	15	0.4	6	1.9	water
B-10	183	15	0.4	6	1.9	water
B-11	183	15	0.8	12	3	water
B-12	61	15	0.8	12	3	water
C-1*	183	15	0			both
C-2	183	15	0.8	12	3	both
C-3	183	15	0.15	23	5.5	both
C-4	183	15	0.4	6	1.9	both
C-5	183	15	0.6	HC		both
C-6	183	15	1.2	HC		both
D-1	183	15	0			oil
D-2	61	15	0			oil
D-3	61	15	1.2	HC		oil
D-4	183	15	1.2	HC		oil
D-5	183	15	0.6	HC		oil
D-6	61	15	0.6	HC		oil
D-7	61	15	0.15	23	5.5	oil
D-8	183	15	0.15	12	5.5	oil
D-9	183	15	0.4	6	1.9	oil
D-10	61	15	0.4	6	1.9	oil
D-11	61	15	0.8	12	3.0	oil
D-12	183	15	0.8	12	3.0	oil

(Continued)

TABLE 128. (Continued)

Test no.	X* (m)	Y* (m)	Waves H (m)	 L (m)	 P (secs)	Oil or water
E-1	183	64	0			oil
E-2	61	64	0			oil
E-3	61	64	0.8	12	3.0	oil
E-4	183	64	0.8	12	3.0	oil
E-5	183	64	0.4	6	1.9	oil
E-6	61	64	0.4	6	1.9	oil
E-7	61	64	0.15	23	5.5	oil
E-8	183	64	0.15	23	5.5	oil
E-9	183	64	0.6	HC		oil
E-10	61	64	0.6	HC		oil
E-11	61	64	1.2	HC		oil
E-12	183	64	1.2	HC		oil

X = Distance between towers
Y = Height of detectors
*Tests designated "C" are automatic scan tests
If possible, the corresponding tests in the "D" series should be done at the same time (i.e, D-1, 4, 5, 8, 9, 12)

Description of Program

The Oil Sensor, Model I, developed for EPA by Rambie, Inc., Irving, Texas, was tested to evaluate its capability to detect quantities of spilled oil. An infrared emitter and sensor were mounted on separate towers at various heights and separations to scan the tank surface under varying sea conditions. Specific operational guidelines for successful monitoring were obtained which include the orientation of receiver and transmitter. Additional information may be obtained from Mr. Donald Jones, WH-548, U.S. Environmental Protection Agency, Washington, DC 20460.

Conclusions

The Scanning Oil Sensor performed well under the field environment offered by the OHMSETT facility. The sensor should now be operated for several months at a field site such as the Port Safety Station on the Houston Ship Channel.

JOB ORDER NO. 38 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	6-8 April 1977	
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817	201-321-6600
Device	Harbor Oil Dispersant Spraying System Warren Springs Laboratory (WSL) Dept. of Industry Gunnels Wood Road Stevenage Herts, SG1 2BX, England	(0438) 3388
Report	Manulio, V.P. Development of an Oil Dispersant Spraying System, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1978 (Ref. 34).	

Description of Program

A harbor oil spill dispersant spraying system was fabricated and tested. System consists of a pump, spray booms and mixing gates and is designed to fit aboard a small vessel of opportunity. Pump and piping are designed to use no-mix and hydrocarbon-based dispersants.

Conclusions

The following conclusions resulted from this series of tests:

1. The modified mixing gates provided the greatest penetration when towed at any speed. At the slower speed, the standard WSL gates dispersed more of the oil slick but with less penetration.

2. At the pump system's minimum operating pressure and flow rate, the tow speed and wind had a negligible effect on the spray characteristics.

3. The wave action aided the riding of the modified gates and disrupted the mixing of the standard gates.

Although one-half of the planned system was tested, the results provided sufficient information to justify completion of the total system. The behavior of the mixing gates illustrated the optimum operating parameters of each design. When low towing speeds and/or shallow waters are encountered, the standard WSL gates would provide the best oil slick agitation. Their shallow penetration would prevent the oil droplets from contacting the sea bed and sticking to it. The modified gates performed best at higher speeds and deeper waters--over three meters in depth. At these conditions the modified gates created maximum agitation and rode best of the two types of mixing gates.

The spray characteristics were not greatly affected by the wind conditions during these tests. At times, the wind gusts and tow speed provide relative wind speeds of up to twenty knots. Further investigation of this behavior is planned, to see if the complete spraying system greatly changes these results.

The need for further data has been recognized and sea trials for this system are now being planned and arranged. After a mount has been fabricated that will lend itself to other vessels other than the EPA's Clean Waters Vessel, the entire system will be field tested in the Upper New York Harbor. This will aid in discovering the best mounting arrangement and operating procedures for later tests. At a later date, after the laboratory studies provide the most effective dispersant and all the required permits are obtained, the dispersant and application system will be tested at an offshore spill of opportunity.

JOB ORDER NO. 39 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 19-23 September 1977

Customer Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Device Oil Gelling Agent
University of Lowell
Chemistry Building
450 Aiken Street
Lowell, MA 01954 617-452-5000

Report Letter Report sent to EPA.

Description of Program

An oil gelling agent consisting of 70% Amine D, 5% ethanol and 15% Nopol was developed by the University of Lowell. Tests were conducted at OHMSETT to

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determine effectiveness of the gelling agent and to identify problems regarding delivery of the agent and CO_2 for catalyzing the gelling process. Contact Mr. Uwe Frank, Oil and Hazardous Materials Spills Branch, U.S. EPA, Edison, New Jersey 08817, for further information.

JOB ORDER NO. 40 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 10-18 November 1977

Customer
Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Device
Resistance Wire Wave Probe
Acoustic Wave Probe
Stevens Institute of Technology
Davidson Laboratories
Castle Point
Hoboken, NJ 07030 201-420-5100

Report Schwartz, S.H. and G.F. Smith. Mechanically Generated Waves at OHMSETT. U.S. Environmental Protection Agency-OHMSETT, Leonardo, New Jersey, 1978 (Ref. 44).

Description of Program

A resistance-wire and acoustic transponder wave probe were utilized during two separate EPA programs to calibrate and quantify the waves produced at OHMSETT. Computer analysis of wave data produced significant heights and spectral densities corresponding to specific test tank positions and wave generator settings. Additional information is available from Mr. J.S. Farlow, Oil and Hazardous Materials Spills Branch, U.S. Environmental Protection Agency, Edison, New Jersey 08817.

JOB ORDER NO. 41 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 21-27 August 1977

Customer
Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Devices
Type 270 Sorbent Boom
3M Company, Inc.
3M Center, 53-4
St. Paul, MN 55101 612-733-3939

Heavy Duty Sorbent Boom
Conwed Corporation
322 Minnesota Street
St. Paul, MN 55101 612-222-3033

Sorbent Boom
Coastal Services, Inc.
22 River Street
Braintree, MA 02184 617-567-6500

Reports Smith, G.F. Performance Testing of Selected Sorbent Booms. EPA-600/7-78-219, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1978. 35 pp (Ref. 47).

Smith, G.F. Deployment Configuration Testing for Improved Selected Sorbent Boom Oil Containment. U.S. Environmental Protection Agency, Cincinnati, Ohio, 1980 (in press) (Ref. 48).

Description of Program

Three commercially available sorbent booms were evaluated by the EPA in various wave conditions, tow speeds, and slick thicknesses. Additional testing was performed to evaluate performance of the sorbent booms when deployed in different ways. Results indicated the maximum successful tow speed for each test condition, the feasibility of boom reuse, and oil/water capacity. A report (EPA-600/7-78-219) is available from NTIS. An EPA report on additional work is in preparation.

Conclusions

Maximum observed no-oil-loss tow speed for the three sorbent booms tested was 0.6 knots in calm water conditions and 0.5 knot in the 0.3 m harbor chop (HC) wave. This figure is lower than the 0.9 knots reported for conventional spill containment booms (with greater draft) in calm water. Average no-oil-loss tow speed during the eleven calm water tests with sorbent booms was 0.4 kts, whereas the average of eleven 0.3 m HC tests was 0.3 knots.

Failure in HC wave conditions occurred as interfacial oil droplet shedding under the boom. Most of the oil splashed onto the boom by the waves was absorbed . Failure in calm water occurred at higher speeds as the oil slick passed under the boom. Oil loss also occurred at the attachment points between boom sections at tow speeds near 0.2 knot well below the failure speed of the entire boom section. Connecting boom sections by overlapping their ends was superior to butt-joining their ends. During towing, the oil slick collected in the apex region; the booms saturated and failed there first.

Using sorbent boom sections in a layered raft configuration is expected to increase the probability that all the sorbent sections will encounter the oil slick. Also, any oil loss at section attachment points of the leading raft rows would be encountered by the trailing rows, thus decreasing the likelihood of ultimate loss. Unfortunately, this boom deployment configuration could not be tested during this program because of time constraints, but it should be examined in later studies.

The lightness of the dry (unused) sorbent booms made handling relatively convenient. Two men can carry and deploy 61 m of boom easily and rapidly. The manufacturers recommended joining sections together by means of integral fasteners (two cases) or by tying the ends together with rope (one case). Based on these tests, we recommend overlapping the ends of adjoining sections to lessen the oil loss between them.

An attempt was made to regenerate the used boom sections by squeezing out the recovered fluid. Each saturated section was pulled between two squeeze rollers (the top roller was filled with water and weighed 250 kg). In all cases, the boom sections were extremely hard to pull through, suggesting the need for a power-operated roller system. A major difficulty with this simple system was that as the booms were pulled through the rollers, the sorbent would bunch up at the end of the covering bag. When this sorbent plug entered the rollers, the resulting pressure would break the bag and the sorbent would fall out. Perhaps two converging, powered conveyor belts might overcome both problems.

The fluid recovered during regeneration weighed 8.5 to 13 times as much as the original (dry) boom and contained 16 to 50 percent oil. This collected oil weighed 2.1 to 4.3 times as much as the boom. It should be noted that only the medium viscosity, naphthenic oil was used in these tests; different oils will yield different results.

TABLE 129. COASTAL SERVICES, INC. ABSORBENT BOOM RESULTS (JO 41)

Test no.	Type of wave	Oil quantity m^3	Oil quantity % of capacity	Maximum no-oil loss tow speed knots	Type of failure	Comments
1A	Calm	0	---	3.5	Boom submersion	Stability (no oil)
2A	0.3 m HC*	0	---	1.0	Splashover	Stability (no oil)
3A	Calm	0.15	25	0.6	Loss under boom	Loss at section ends occurs at .1 kt
4A	0.3 m HC	0.15	25	0.2	Loss under boom	"
5A	Calm	0.30	50	0.4	Loss under boom	"
6A	0.3 m HC	0.30	50	0.2	Droplet shedding from slick	"
7A	Calm	0.45	75	0.3	Loss under boom	"
8A	0.3 m HC	0.45	75	0.2	Droplet shedding	"
9A	Calm	0.60	100	0.3	Loss under boom	"
10A	0.3 m HC	0.60	100	0.3	Droplet shedding	"
11A	Calm	0.75	125	0.4	Loss under boom	"
12A	0.3 m HC	0.75	125	0.3	Loss under boom	"

*HC = harbor chop

TABLE 130. 3M COMPANY TYPE 270 SORBENT BOOM RESULTS (JO 41)

Test no.	Type of wave	Oil quantity m^3	Oil quantity % of capacity	Maximum no-oil loss tow speed knots	Type of failure	Comments
1B	Calm	0	---	2.4	Boom submersion	Stability (no oil)
2B	0.3 m HC	0	---	1.5	Splashover	Stability (no oil)
3B	Calm	0.60	25	0.4	Loss under boom	
4B	0.3 m HC	0.65	25	0.3	Loss under boom	
5B	Calm	1.21	50	0.5	Loss under boom	
6B	0.3 m HC	1.21	50	0.4	Droplet shedding under boom	Creases developed in boom sections and oil loss occurred at creases
7B	Calm	1.82	75	0.5	Loss under boom	Loss at creases occurred at 0.3 kt
8B	0.3 m HC	1.82	75	0.3	Droplet shedding	
9B	Calm	2.42	100	0.5	Droplet shedding	Loss at creases occurred at 1 kt
10B	0.3 m HC	2.42	100	0	Splashover	Some boom sections saturated and almost submerged

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TABLE 131. CONWED CORPORATION HEAVY DUTY SORBENT BOOM RESULTS (JO 41)

Test no.	Type of wave	Oil quantity		Maximum no-oil loss tow speed knots	Type of failure	Comments
		m^3	% of capacity			
1C	Calm	0	---	2.4	Boom submersion	Stability (no oil)
2C	0.3 m HC	0	---	1.4	Splashover	Stability (no oil)
3C	Calm	0.53	25	0.4	Loss under boom	Loss at section ends occurred at 0.2 kts
4C	0.3 m HC	0.53	25	0.5	Loss under boom	Loss at section ends occurred at 0.4 kts
5C	Calm	1.06	50	0.5	Loss under boom	
6C	0.3 m HC	1.06	50	0.4	Loss under boom	Apex of boom was becoming saturated
8C	0.3 m HC	1.59	75	0.2	Splashover	Apex of boom became saturated and nearly submerged

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SECTION 8

TESTS PERFORMED IN 1978

JOB ORDER NO. 42 - U.S. ENVIRONMENTAL PROTECTION AGENCY, U.S. COAST GUARD, U.S. NAVY, U.S. GEOLOGICAL SURVEY

Dates	15-26 May 1978 10-21 July 1978 24 October - 1 November 1978	
Customers	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817	201-321-6600
	Office of Research & Development U.S. Coast Guard G-DMT-4/TP54 Washington, DC 20593	202-426-1023
	Naval Facilities Engineering Command 200 Stovall Street Hoffman Building #2 Alexandria, VA 22332	202-545-6700
	U.S. Geological Survey National Center U.S. Department of Interior MS620 Reston, VA 22092	703-860-7549
Devices	Water Jet Oil Herder OHMSETT P.O. Box 117 Leonardo, NJ 07737	201-291-0680
	OSD Scoop 250 Offshore Devices, Inc. Summit Industrial Park, Bldg. 43 Peabody, MA 01960	617-581-6404
	OMI Zero Relative Velocity (ZRV) Skimmer Oil Mop, Inc. Engineers Road, P.O. Drawer P Belle Chasse, LA 70037	504-394-6110

Framo Oil Skimmer ACW-402
Frank Mohn A/S
P.O. Box 98
N5051, Nesttun
Bergen, Norway 05-10-06-00

Reports

Breslin, M.K. and M.G. Johnson. Testing of a Coherent Water Stream Concept for Oil Spill Herding. U.S. Environmental Protection Agency, Cincinnati, Ohio, 1980 (in preparation) (Ref. 11).

Graham, D.J., R.W. Urban, M.K. Breslin, and M.G. Johnson. OHMSETT Evaluation Tests: Three Oil Skimmers and a Water Jet Herder. EPA-600/7-80-020, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1980. 110 pp (Ref. 25).

Description of Program

These studies were sponsored through an interagency agreement between the EPA, the USCG, the USGS, and the USN. This second successful joint test program at OHMSETT was divided into four separate studies.

The first test series evaluated the new "Scoop", a self-contained vessel with a skimming boom designed by Offshore Devices, Inc. Performance was evaluated for both the total system and the individual parts including the weirs, boom, and oil/water separator.

The second program evaluated a new deployment concept of an Oil Mop system which may be used on a large vessel of opportunity. Rigging alternates are currently being evaluated for recommendation to field users.

The third test series looked at a new disc skimmer from Norway designed and built by Frank Mohn A/S, which could be used on a vessel of opportunity in open seas. The device is intended to collect spilled oil contained in a boom. It consists of a combination disc/weir stationary skimmer head deployed by a sophisticated hydraulic crane.

The fourth test program, inspired by the need to distribute oil slicks in OHMSETT to advancing skimmers being tested, utilized a water jet to improve oil slick width control. The water jet proved more successful in containing oil slicks in large waves or choppy waters than the trailing booms and braided ropes previously used. Included in testing was a study of the field user's problems of coupling a large standard skimmer into the apex of a boom.

An OHMSETT-designed water jet prototype system was integrated with a boom and a skimmer to effectively prevent oil spillage/entrainment near the boom apex and skimmer bow in large waves and fast tow speeds. This program is a prime example of how OHMSETT experience can contribute to spill control technology. A 16 mm movie film entitled, "OHMSETT Evaluation Tests: Three Oil Skimmers and a Water Jet Herder" is available from the Oil and Hazardous Materials Spills Branch, U.S. EPA, Edison, New Jersey 08817.

Conclusions

Water Jets

A total of 53 performance tests were conducted with a vertical water jet boom-to-skimmer transition system. The water jet devices and mounting brackets were fabricated by OHMSETT operating personnel. The U.S. Navy Supervisor of Salvage provided the lengths of oil containment boom and LPI, Inc. provided the oil skimmer towed behind the Navy boom. This section summarizes the conclusions of the two week test series in four major areas:

1. Best Performance
2. Operating Limits
3. Mechanical Problems
4. Device Modifications

Best Performance. OHMSETT testing of the water jet device was conceived, planned, and executed in a two-week period.

Due to the experimental nature of the concept and the short time period available for component fabrication, the best possible performance of the water jet boom-to-skimmer transition device has not been firmly established.

Although inconclusive, the best performance of the concept, as measured by the percent reduction in slick width at the skimmer bow over the value when no jets are operating, is presented in Table 132 for heavy and light oils.

$$\% \text{ Reduction Slick Width} = \frac{W_o - W_j}{W_o}$$

Where: W_o = Slick width at skimmer bow, no jets operating (measured data)

W_j = Slick width at skimmer bow, "j" jets operating (measured data)

TABLE 132. BEST PERFORMANCE - WATER JET, HEAVY AND LIGHT OIL (JO 42)

Performance parameter	Highest value	Tow speed knots	Wave H x L (m x m)	Number of water jets
% Slick width reduction, heavy oil	73%	2	Calm	4
% Slick width reduction, light oil	66%	3	Calm	8

Based on the performance observed during these brief tests, it appears that a system of vertical water jets, properly sized and positioned on the converging boom and/or bow of a skimmer is superior to the traditional solid skirt boom/skimmer connection in concentrating and directing an oil slick into the skimmer.

Operating Limits. The operating limits of the water jet boom/skimmer transition device need to be more clearly defined with future tests. However, based on the results of this initial feasibility test, the operating limits of the water jet boom/skimmer transition device appear to depend upon the following factors:

1. The number and position of water jets appeared to be more important than changes in water supply pressure.

2. Although non-breaking waves do not affect water jet performance, breaking waves can overpower the oil slick holding capability of the jets and entrain oil downward in the water jet stream.

3. Trailing vortices at the boom catenary opening at higher tow speeds have an effect on the oil slick exiting the boom in spite of the presence of the water jet.

4. When the water jets became angled backward toward the boom skirt due to the top-heavy boom tipping forward and planing, oil was entrained by the jets. When the jets were angled forward so that the floating oil slick first encountered a water surface elevation ahead of the jet impact point, the oil was usually directed around the jet impact point with little oil entrainment.

Mechanical Problems. The primary problem encountered in this initial feasibility test was the tendency of the boom, made top-heavy with the attachment of the water jet piping, to roll forward and plane during the test tow. This was corrected by employing tie lines at the top and bottom of the booms across the "V". If the booms were allowed to plane, the water jet would be directed away from a vertical position to a more horizontal, backward facing one. This could cause the jet to draw parts of the oil slick into the jet impact zone rather than drive oil away from the point of impact as is the case when the water jet is vertical to the water surface. It is felt that with more time available for rigging, the water jet technique can be retested at various angles of jet impingement with the water surface.

Device Modifications. Presence of the converging booms caused strong currents and vortices near the boom and also tipping of the jets from their downward facing vertical attitude (boom planing). A modification of this concept which merits further testing is to employ vertical water jets alone to concentrate and herd an oil slick into a trailing skimmer. Without a boom present, the water jets could be maintained in a more nearly vertical attitude and the vortices and local turbulence caused by water flow along the boom catenary and at the opening in front of the skimmer would be eliminated. Wave chop buildup in front of the skimmer due to wave reflection off the converging boom lengths would also be eliminated.

Whether mounted on a skimmer, length of boom, or separate float, additional tests should be conducted using water jet mountings designed so that the near-vertical attitude of the jet can be maintained at all times. This seems to be important to maintain a radial zone around the impact point so that the oil slick is diverted away from the impact point instead of being drawn into the impact point and emulsified into the water column.

Offshore Devices, Inc. Scoop Skimmer

A total of 23 tests were run with high viscosity (heavy) oil and 10 tests with low viscosity (light) oil. This section summarizes the conclusions of the eight days of testing in four major areas:

1. Best Performance
2. Operating Limits
3. Mechanical Problems
4. Device Modifications

Best Performance. Best ORR performance for the Scoop skimmer occurs with large amounts of oil (greater than 4 m^3) in the barrier catenary. Under these conditions, recovery of pure oil is limited only by the pump capacity of 51 m^3/hr. The present tests were performed with smaller volumes of oil in the barrier to evaluate Scoop operation near the end of a spill cleanup operation and to determine how the separator and weirs function with thinner slicks.

Best skimmer performance (highest numerical results) achieved during these tests is presented, along with accompanying test conditions, in Tables 133 and 134. As a result of the skimmer operating principle, the highest value for each of the parameters TE, RE, and ORR did not occur under the same test conditions. Of special interest in Table 133 is the best performance exhibited by the oil/water separator (as measured by the RE value). The separator was designed to fully separate oil and water (RE = 100%) at a fluid (oil and water) flowrate no greater than 11.9 m^3/hr. However, as shown in Table 133, a 100% RE value (indicating that complete oil-water separation was taking place in the separator), was obtained for a fluid flowrate of 49 m^3/hr with heavy oil, four times the design flowrate.

TABLE 133. BEST PERFORMANCE - OSD SCOOP, HEAVY OIL (JO 42)

Performance parameter	Highest value	Tow speed knots	Wave H x L (mxm)	O/W* sep flowrate m^3/hr	Test no.
TE	100%	0.75	0.6 HC	22.7	27
RE	100%	1.0	0	49	19
ORR	11.5 m^3/hr	0.75	0.3 x 9	15.5	15

*O/W sep = oil and water separator

TABLE 134. BEST PERFORMANCE - OSD SCOOP, LIGHT OIL (JO 42)

Performance parameter	Highest value	Tow speed knots	Wave H x L (mxm)	O/W sep flowrate m^3/hr	Test no.
TE	89%	0.75	0	11.9	8
RE	26%	0.75	0	36.4	3
ORR	7.6 m^3hr	0.75	0	19.8	6

Operating Limits. Based upon both quantitative and qualitative observations during these tests, the operating limits of the Scoop skimmer appear to depend on the following three factors:

1. Oil loss past a vertical containment barrier-- Tow oil loss mechanisms of near-boom drainage and head-wave droplet entrainment were both observed. The strengths of these two mechanisms depended upon the initial precharge oil volume placed in the barrier at the start of each test, the pumping rate during the test, the tow speed, and the wave condition. Most oil losses were observed to be a result of droplet entrainment. Drainage failure was observed on only a few wave tests. Visual observation of the area astern the Scoop barrier catenary indicated that significant oil loss began at a tow speed of about 1 knot for light oil and at a slighly higher speed of about 1.25 knot for heavy oil. An insufficient number of tests were conducted to determine these limits more precisely. This could have been the result of the low interfacial tension measured for the light oil used in the testing.

2. Oil/water separator volume-- Performance of the present separator exceeded its design maximum flowrate limits of 11.9 m^3/hr with heavy oil. No oil appeared at the separator water discharge hose, indicating that complete settling of the oil/water mixture was occurring for flowrates as high as 49 m^3/hr. For light oil, incomplete settling (indicated by oil appearing at the water discharge hose) was observed at the separator design flowrate of 11.9 m^3/hr. An increase in separator volume would allow a higher throughput flowrate with more complete settling for all types of oil. Such an increase in flowrate would reduce the length of time required to pump a given oil volume from in front of the weirs. Since the cumulative oil lost under the Scoop barrier increases with time, a shorter pumping time would mean less loss and higher throughput efficiency.

3. Workboat stern tow-- One of the operating modes of the Scoop skimmer is with the workboat towed stern to the towing direction and the skimming barrier attached to the bow. The Scoop workboat tested at OHMSETT was obtained from the manufacturer before a full height internal transom could be installed. The importance of a full height internal transom forward of the outboard motor space was confirmed

when, while waiting for a test to begin, the boat filled with water due to wave splash over the outboard motor cutout. This caused the boat to fill with water and swamp.

Since these OHMSETT tests, the manufacturer has conducted an inclining experiment to demonstrate the result that the riding moment of the Scoop workboat is reduced by only 10% when the onboard separator is filled with water.

Mechanical Problems. There were no problems with the 21 m long skimming barrier during the two week test. The barrier proved to be very rugged, and the attached external tension lines did not snag or tangle during the many changes in tow direction up and down the tank.

The lightweight flexible suction hose connecting the skimming struts to the diaphragm pump was partially collapsed by the test crew in the course of normal activity aboard the boat. In addition, it was abraided against the workboat rails by the surging action of the diaphragm pump.

The hydraulic control system that drives the double diaphragm pump developed problems toward the end of the test series. Erratic operation caused the pump flowrate (set at the beginning of the test) to drop significantly and in some cases to fall to zero during the test run. Despite several interruptions in the test series to clean out the control elements (there was no filter in the hydraulic oil circuit) and to reduce oil temperature with the addition of a coiled length of copper tubing placed over the side, the problem was never completely resolved. The manufacturer has subsequently evaluated this problem following the OHMSETT test. The control problem proved to be related to a low viscosity hydraulic oil which was used in the control system after the workboat swamped and capsized following the light oil tests. The manufacturer has redesigned the hydraulic control elements to eliminate this viscosity dependence.

The plexiglass separator vent standpipe was found to be quite fragile and was accidentally broken off during initial Scoop assembly prior to the start of testing. This plexiglass vent standpipe has now been replaced with a stronger lexan pipe by the manufacturer.

The standpipe height was insufficient for some of the heavy oil tests, as shown when the separator discharge valve was moved from the 100% water to 100% oil position. Oil then surged up to overflow the top of the standpipe because of the greater hydrostatic head required to push settled heavy oil out of the separator into the OHMSETT collection barrel onboard the workboat. The standpipe height might not be a problem when the collapsible storage bag is used to receive settled oil from the separator. As the separator was designed, this collapsible storage bag is at the waterline elevation, thereby reducing the head in the standpipe above the separator necessary to push heavy oil into the storage bag.

Device Modifications. The only modifications made to the Scoop (as supplied) was the addition of a copper cooling coil for the hydraulic control system. This modification did not improve the smoothness or reliability of the hydraulic control circuit in operating the diaphragm pump.

Oil Mop, Inc. VOSS Concept

During the period July 10-21, 1978, 41 oil pickup performance tests were conducted to determine the feasibility of the Oil Mop, Inc. VOSS (Vessel of Opportunity Skimmer System) Concept. A total of 22 tests were conducted with high viscosity (heavy) oil and 19 tests with low viscosity (light) oil. This section summarizes the conclusions of the feasibility tests in four major areas:

1. Best Performance
2. Operating Limits
3. Mechanical Problems
4. Device Modifications

Best Performance. Best skimmer performance (highest numerical results) obtained during the feasibility tests are listed together with test tank and Oil Mop VOSS deployment conditions in Tables 135 and 136. In accordance with the operating principle of the oleophilic oil mop and the different deployment configurations used, the highest value of the TE, RE, and ORR parameters did not occur under the same test conditions. Test results demonstrate that the Oil Mop VOSS concept shows excellent promise as an oil pickup system for open ocean use. Based upon both visual observation and quantitative data results, the concept consistently demonstrated:

1. Excellent wave conformance of the flexible rope mop.

2. Good retention of sorbed oil on the mop surface even when the mop was submerged and subjected to local perpendicular currents.

3. ORR and TE values limited chiefly by the ability of the deployment technique to maximize the percentage of the oil slick brought into contact with the mop.

TABLE 135. BEST PERFORMANCE - OIL MOP VOSS CONCEPT, HEAVY OIL (JO 42)

Performance parameter	Highest value	Tow speed knots	Wave H x L (mxm)	No. mops	Deploy. config.
TE	25%	1.5	0.6HC	2	I
RE	68%	1.5	0	1	I
ORR	11.1 m^3/hr	1.5	0.6HC	2	I

TABLE 136. BEST PERFORMANCE - OIL MOP VOSS CONCEPT, LIGHT OIL (JO 42)

Performance parameter	Highest value	Tow speed knots	Wave H x L (mxm)	No. mops	Deploy. config.
TE	37%	3	0.6 HC	1	IV
RE	48%	1.5	0	1	IV
ORR	14.8 m^3/hr	3	0	2	I

Operating Limits. None were established for the Oil Mop VOSS concept during these initial feasibility tests. More testing needs to be performed with equipment especially designed for the VOSS application. However, the concept's limits appear to depend on the single factor of the deployment method that determines percentage of oil slick contacted by the mop(s). Within the time and budget constraints of the present test series, different mop deployment methods were studies, using both single and double lengths of oil mop. The floating portion of the oil mop lengths in all configurations appeared to be saturated very quickly by those portions of the oil slick directly beneath or (in waves) within a distance of one to two mop diameters on either side of the mop(s). Other portions of the slick outside these regions were too far away from the mops to be brought into contact by the action of waves or by the low viscosity of the mops relative to the water. These portions of the slick were merely deflected out of the way and lost behind the oil mops.

Secondary limiting factors, which were dealt with by temporary rigging during the feasibility tests were:

1. Loss of oil at squeezing mop engine-- Some oil was scraped off the saturated mops against the auxiliary birdge and mop engine structural members as the oil-laden mop was pulled out of the water into the oil mop squeezing engine.

2. Non-uniform mop strand density-- Jerking motion of the oil mop during its travel around its deployment circuit caused a variation in tension, intermittently lifting the oil-soaked length of mop up out of the slick. The jerking was caused by slight bunching of oil mop strands at various points along the mop.

3. Jamming of the oil mop engine-- On a few runs the low tension mop portion leaving the squeezing engine became entangled in the mop entering the engine. The entrainment caused the mop to wrap around a squeeze roller, stalling the movement of mop(s) around the deployment circuit.

Mechanical Problems. No problems were encountered during the two week test series with any of the mechanical components of the MK II-9D oil mop engines. The diesel engine proved to be very reliable, and the roller assemblies were easily worked on in the few cases of mop engine jams.

The MK II-9D engines and mops used in these tests were operated before arrival at OHMSETT at the Oil Mop, Inc. plant in Belle Chasse, Louisiana to determine the maximum non-jamming rotational speeds with the standard gearing and two lengths of oil mop. It was demonstrated in these checkout tests that two 50-m mop lengths could be powered around a triangular circuit without jamming at speeds up to 3 knots. The checkout tests, however, could not be performed with oil.

During the oil tests at OHMSETT, a few jams of the MK II-9D engines were experienced because the mop tended to stick to protruding metal parts of the OHMSETT bridge and to the oil mop engine as it was pushed out of the engine after squeezing.

Smooth uniform speed adjustment of the mop sections floating in the oil slick was difficult because of a variation in mop strand density along its length. This bunching of the mop strands caused tugging and sudden changes in tension as the mop was pulled through the squeeze rollers. The presence of the lube-type test oil, especially the heavy oil, lubricated the mop/squeeze roller contact area, contributing to a loss of tension control. A compressed air jet was used to more completely remove oil from the mop and to reduce slippage of the mop against the rollers, but this was not successful.

The non-powered mop tail pulleys provided for the feasibility tests were designed for low-speed operation while floating on the water surface. In these tests, the pulleys were suspended at various angles above the water by tying them off the video truss and operating at higher than normal speeds. Oil mop jams at the tail pulleys occurred until they were modified.

Device Modifications. The modifications performed during the two-week feasibility tests and the effect they had on observed performance were:

1. Polyethylene chutes-- A 3 mm thick polyethylene sheet attached to each MK II-9D mop engine below the rollers reduced friction of the squeezed mop when it was pushed out of the oil-laden mop when it was lifted off the surface by the trailing engine. These two sheets were instrumental in minimizing the number of oil mop jams experienced during the two weeks. Because of the changes in vertical angle of the oil-soaked mop when it was lifted out of the water under various wave conditions, placement of the polyethylene sheet was not optimal for some tests. The result was that a small amount of oil had to be scraped off the mop.

2. Modified non-powered tail pulley-- A piece of tubing was placed across the top of the fiberglass non-powered pulley wheel to prevent the oil mop from jumping over the top and jamming between the support axle and rotating pulley. This was effective in eliminating the jamming of the oil mop at the tail pulleys.

Framo ACW-402 Skimmer

The Framo ACW-402 open sea high capacity oil skimmer was tested during the period of October 23 to November 3, 1978. A total of 74 oil pickup performance tests were conducted; 36 tests were run with high viscosity (heavy) oil, and 38 tests were run using medium viscosity (medium) oil. This section summarizes the conclusions of the two-week test series in the four major areas of:

1. Best Performance
2. Operating Limits
3. Mechanical Problems
4. Device Modifications

Best Performance. The Framo skimmer was designed for high volume recovery of spilled oil from thick slicks held inside offshore containment barriers. Due to the constraints of oil volume and tank time, the maximum oil recovery rate was not obtained for the Framo unit during this test series. If the oil slick is thick enough, the recovery rate is bounded only by the maximum pump flow rate under the existing conditions of oil (emulsion) viscosity and the discharge hose head losses. A maximum flowrate test with water was conducted near the end of this test series, yielding a maximum pump rate against a 5 m head of approximately 526 m^3/hr. Oil tests run during this series used slick thicknesses from 6 mm to 160 mm. The best skimmer performance (highest numerical results) obtained is shown in Tables 137 and 138. Since the Framo skimmer is a stationary skimmer, the throughput efficiency was not calculated. Because of the Framo operating principles of both overflow weirs and rotating discs, the highest value of the RE and ORR parameters presented in Tables 137 and 138 did not occur under the same test conditions.

TABLE 137. BEST PERFORMANCE - FRAMO ACW-402, HEAVY OIL (JO 42)

Performance parameter	Highest value	Wave H x L (m x m)	Average slk. thk. (mm)	Weir H (cm)	Disc speed (RPM)	Test no.
RE	96%	0	73	0	4	18
ORR	97.2 m^3/hr	0	79	-2	20	23

TABLE 138. BEST PERFORMANCE - FRAMO ACW-402, MEDIUM OIL (JO 42)

Performance parameter	Highest value	Wave H x L (m x m)	Average slk. thk. (mm)	Weir H (cm)	Disc speed (RPM)	Test no.
RE	92%	0	73	0	10	31
ORR	93.6 m^3/hr	0	43	-5	20	36
ORR	190.8 m^3/hr	0	138	-5	20	42

The test results consistently demonstrated that--depending on slick thickness, wave conditions, operational time available at the spill site, and available storage capacity for the recovered oil/water mixture--the skimmer may be operated with:

1. Overflow weir above the still water surface, resulting in a high RE value but a reduced ORR value (for thin slicks, short waves or limited storage capacity)

2. Overflow weir below the still water surface to achieve maximum ORR at the expense of the RE value (for thick slicks, long waves, or large storage capacity)

In almost every wave and test slick thickness condition, moving the Framo skimmer head around in the slick increased the RE and ORR over the values obtained with the skimmer held stationary in a stationary mode.

Operating Limits. Operating limits of the Framo 402 skimmer depend upon the following factors:

1. Slick thickness-- For slick thicknesses greater than those used in this test series (160 mm), the ORR (m^3/unit time) is limited only by the oil (or emulsion) viscosity and the head loss through the discharge hose. For operation in thin slicks, the weir is raised above the water surface, and only the discs are used to collect oil. This method maintains a high recovery efficiency, but at a sacrifice in the oil recovery rate. This was verified by a single test at a slick thickness of 6 mm. In this test the RE was measured at 85%.

2. Waves with periods less than 6 seconds-- The in-phase heave response of the skimmer head is limited to waves with periods of 6 seconds or greater impacting the skimmer head at right angles to the disc assemblies. This is because of the design of the following components:

   a. The passive hydraulic compensating circuit in the control arm for wave following.

   b. The mass and floatation area of the skimmer head.

   Waves of periods less than 6 seconds and small breaking wavelets were observed breaking through the disc assemblies and carrying water directly into the interior weir box of the skimmer.

Mechanical Problems. No problems were encountered during the two week test series with any of the mechanical or hydraulic components of the Framo skimmer. The skimmer was operated for a total of 26 engine hours during the two week test series. Near the end of the test series, it was noticed that some plastic wipers had worked loose from the disc assemblies. Although incomplete scraping of the discs occurred as a result, the discs still seemed to perform their primary function of thickening the slick at the overflow weir lip.

From the control cab of the skimmer, easy operation was maintained of the five skimmer control settings:

1. Disc speed
2. Disc rotation

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TABLE 139. TEST RESULTS - OSD SCOOP HEAVY OIL(1) (JO 42)

Test no.	Tow speed knots	Wave H x L (m x m)	Oil pre-charge (m^3)	No. weir	O/W sep.[7] flowrate m^3/hr	Sep. dis. valve(2)	Vol. pumped through sep. (m^3)	Weir RE (%)	RE (%)	TE (%)	ORR m^3/hr
15	0.75	0.3x9	1.16	4	15.5	(3)	(3)	53	(3)	88	11.5
16	0.75	0.3x9	1.13	2	15.5	(3)	(3)	58	(3)	93	9.7
18	1.0	0	1.14	4	25.6	w	1.84	(4)	(6)	49	6.5
19	1.0	0	1.14	4	49.0	w	3.47	60	100	44	6.5
20	0.75	0	1.12	4	49.0	w /o	4.90	50	87	100	10.1
21	1.25	0	1.15	4	16.9-49	w	(4)	25	(5)	46	3.0
22	0.5	0	1.15	2	10.8	w	1.36	40	(6)	100	9.0
23	0.5	0	1.15	4	36.4	w /o	4.24	48	57	100	9.4
24	0.75	0	0.90	4	18.4-23.8	w	(5)	(4)	(5)	100	(4)
25	1.25	0	1.15	4	22.7-36.4	(3)	(3)	20	(3)	43	(4)
26	1.25	0	1.15	4	19.8-22.7	w	(5)	10	(5)	26	6.1
27	0.75	0.6 HC	1.15	4	22.7	w /o	1.96	45	(6)	100	(4)
28	0.75	0	1.15	4	5.8	w	0.52	75	(6)	100	(4)
29	1.0	0	1.15	4	11.2	w	0.89	40	(6)	82	4.3
30	1.25	0	1.16	4	11.2	w	0.69	10	(6)	17	3.2
31R	0.75	0.6 HC	1.15	4	11.2	w	1.13	10	(6)	35	4.0
32	1.0	0.6 HC	1.16	4	11.2	w	0.95	30	(6)	70	5.4
33	1.25	0.6 HC	1.15	4	11.2	w	0.76	10	(6)	21	3.0
34	1.0	0.6 HC	1.16	4	34.2	w	2.55	35	95	81	9.0
35	1.25	0.6 HC	1.16	4	22.7	w	1.51	20	(6)	37	6.5
36	0.5	0.6 HC	1.15	4	22.7	w	3.03	10	100	57	4.7
37	0.75	0.6 HC	1.15	4	36.4	(4)	3.18	36	(4)	70	6.8
38	1.0	0.6 HC	1.18	4	24.5	(4)	1.94	30	(6)	56	5.8

1. Average viscosity: 1000 cst.
2. Position of separator discharge valve during test run was w/o = valve lever to 100% water discharge at the beginninng of run; it then moved toward 100% oil discharge, as necessary, during run to keep water discharge hose clear of oil; w = valve lever remained at 100% water position during entire run.

3. Test started with separator empty.
4. No data.
5. Pump hydraulic controls unsteady during test, volume pumped not known.
6. RE reported only if separator reached steady state during run--i.e. volume pumped through separator greater than or equal to 2 times (volume separator) = 2 x (1.3 m^3) = 2.6 m^3.
7. O/W sep. = oil/water separator

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TABLE 140. TEST RESULTS - OSD SCOOP, LIGHT OIL(1) (JO 42)

Test no.	Tow speed knots	Wave H x L (m x m)	Oil pre-charge (m^3)	No. weir	O/W sep.[5] flowrate m^3/hr	Sep. dis. valve(2)	Vol. pumped through sep. (m^3)	Weir RE (%)	RE (%)	TE (%)	ORR m^3/hr
3	0.75	0	0.60	4	36.4	w /o	3.48	20	26	70	4.3
4	0.75	0.3x9	0.61	4	36.4	w /o	3.23	14	18	82	3.6
5	0.75	0	0.62	4	36.4	w /o	3.23	20	25	83	5.0
6	0.75	0	1.35	4	19.8	w /o	1.77	42	(4)	72	7.6
7	0.75	0	0.60	4	25.6	w /o	2.68	19	20	87	3.6
8	0.75	0	0.61	4	11.9	w /o	1.05	14	(4)	89	3.0
10	1.25	0	1.17	2	11.9	w	0.65	38	(4)	11	2.2
11	1.0	0	1.18	2	11.9	w	0.79	34	(4)	42	5.0
12	1.0	0.3x9	1.24	2	11.9	w	0.75	26(3)	(4)	29	4.0
13	0.75	0.3x9	1.24	2	11.9	w	1.02	26(3)	(4)	64	3.6

1. Average viscosity: 17.8 cSt.

2. Position of separator discharge valve during test run was w/o = valve lever to 100% water discharge at the beginninng of run; it then moved toward 100% oil discharge, as necessary, during run to keep water discharge hose clear of oil; w = valve lever remained at 100% water position during entire run.

3. Samples recovered out of order, boat capsized with samples from both Test 12 and 13.

4. RE reported only if separator reached steady state during run--i.e. volume pumped through separator greater than or equal to 2 times (volume separator) = 2 x (1.3 m^3) = 2.6 m^3.

5. O/W sep. = Oil and water separator.

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TABLE 141. THROUGHPUT EFFICIENCY VERSUS SEPARATOR FLOW RATE, HEAVY OIL (JO 42)

Test no.	Tow speed knots	Wave H x L (mxm)	O/W sep.[1] flowrate (m^3/hr)	TE (%)
22	0.5	0	10.8	100
23	0.5	0	36.4	100
28	0.75	0	5.8	100
24	0.75	0	11.2-23.8	100
20	0.75	0	49	100
31R	0.75	0.6 HC	11.2	35
27	0.75	0.6 HC	22.7	100
37	0.75	0.6 HC	36.4	70
15	0.75	0.3x9	15.5	88
16	0.75	0.3x9	15.5	93
29	1.0	0	11.2	82
18	1.0	0	25.6	49
19	1.0	0	49.0	44
32	1.0	0.6 HC	11.2	70
38	1.0	0.6 HC	24.5	56
34	1.0	0.6 HC	34.2	81
30	1.25	0	11.2	17
26	1.25	0	19.8-22.7	26
25	1.25	0	22.7-36.4	43
21	1.25	0	16.9-49	46
33	1.25	0.6 HC	11.2	21
35	1.25	0.6 HC	22.7	37

1. O/W sep. = Oil and water separator

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TABLE 142. TEST RESULTS - OIL MOP VOSS CONCEPT, HEAVY OIL(1) (JO 42)

Test no.	Tow speed knots	Wave H x L (m x m)	Total oil dist.(2) (m^3)	No. mops	Oil deploy. config.(3)	Oil picked up (m^3)	RE (%)	RE(4) (%)	ORR m^3/hr
A1	1.5	0	1.44	1	I	0.142	34	---	4.3
A2	1.5	0	1.32	1	I	0.126	68	19	3.9
A3	1.5	0	1.37	1	I	0.149	67	14	4.5
A4	1.5	0.15x3.3	1.36	1	I	0.187	63	---	5.7
A5	1.5	0.15x3.3	1.39	1	I	0.176	62	---	5.2
A6	2.5	0	1.21	1	I	0.132	59	18	6.6
A7	2.5	0	1.36	1	I	0.129	50	16	6.4
A8	3	0	1.43	1	I	0.115	35	---	6.8
B1	1.5	0	1.57	1	I	0.107	50	---	3.2
B2	1.5	0	1.42	1	I	0.134	68	19	4.1
B3	1.5	0.15x3.3	1.41	1	I	0.215	58	---	6.4
B4	2.5	0.15x3.3	1.42	1	I	0.121	54	---	5.9
B5	2.5	0.15x3.3	1.34	1	I	0.182	51	---	9.1
B6	3	0.15x3.3	1.29	1	I	0.104	55	---	6.4
B7	1.5	0.6 HC	1.09	1	I	0.193	54	23	5.9
B8	2.5	0.6 HC	1.23	1	I	0.112	49	---	5.7
B9	3.0	0.6 HC	1.36	1	I	0.084	46	---	5.0

(Continued)

TABLE 142. (Continued)

Test no.	Tow speed knots	Wave H x L (m x m)	Total oil dist.(2) (m^3)	No. mops	Oil deploy. config.(3)	Oil picked up (m^3)	RE (%)	RE(4) (%)	ORR m^3/hr
C1	1.5	0	1.34	1	I	0.150	57	15	4.5
C4R	1.5	0	1.43	1	I	0.149	57	13	4.5
C5	2.5	0	1.23	1	I	0.157	59	15	7.8
E2	1.5	0	1.42	2	I	0.262	37	25	8.0
E3	1.5	0.6 HC	1.34	2	I	0.354	51	25	11.1

1. Average viscosity: 793 cst.

2. Nominal slick thickness of 5 mm.

3. Mop(s)-to-slick contact length variable over run. TE reported only when visual estimate of encounter percentage was available.

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TABLE 143. TEST RESULTS - OIL MOP VOSS CONCEPT, LIGHT OIL(1) (JO 42)

Test no.	Tow speed knots	Wave H x L (mxm)	Total oil dist.(2) (m^3)	No. mops	Oil deploy. config.(3)	Oil picked up (m^3)	RE (%)	RE(4) (%)	ORR m^3/hr
F2	1.5	0	1.34	2	I	0.349	45	---	10.4
F3	2.5	0	1.32	2	I	0.231	41	---	11.6
F4R	3.0	0	1.30	2	I	0.246	39	---	14.8
F5	1.5	0.6 HC	1.53	2	I	0.397	38	---	11.9
F6	2.5	0.6 HC	1.39	2	I	0.145	19	---	7.3
F7	3.0	0.6 HC	1.37	2	I	0.155	26	---	9.3
S1	1.5	0	1.40	2	II	0.105	23	25	3.2
S2	3.0	0	1.24	2	II	0.103	38	21	6.1
T1	1.5	0	1.61	2	III	0.216	38	---	6.4
T2	3.0	0	1.24	2	III	0.150	38	---	9.1
T3	1.5	0.6 HC	1.47	2	III	0.264	35	---	8.0
T4	3.0	0.6 HC	1.34	2	III	0.166	34	---	10.0
I1	1.5	0	1.35	1	IV	0.224	45	---	6.8
I2	3.0	0	1.27	1	IV	0.121	35	19	7.3
I3	1.5	0.6 HC	1.18	1	IV	0.271	48	---	10.9
I4	3.0	0.6 HC	1.31	1	IV	0.196	47	37	11.8
I10	1.5	0	1.33	1	IV	0.147	48	19	4.3
I11	3.0	0	1.31	1	IV	0.072	43	14	4.3
I12	1.5	0.6 HC	1.19	1	IV	0.134	43	---	5.4

1. Average viscosity: 15 cSt.
2. Nominal slick thickness of 5 mm.
3. Mop(s)-to-slick contact length variable over run. TE reported only when visual estimate of encounter percentage was available.

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TABLE 144. TEST RESULTS - FRAMO SKIMMER, HEAVY OIL(1) (JO 42)

Test no.	Slick thk. (mm)	Wave H x L (mxm)	Weir height (cm)(2)	Disc speed, (RPM)	Skimmer deploy-ment(3)	Oil rec. (m^3)	RE (%)	ORR m^3/hr
93	79	0.19 HC	8	20	S	1.69	82.3	6.8
94	84	0.19 HC	0	20	S	1.49	76.0	15.1
95	64	0.19 HC	-5	20	S	0.88	42.0	26.6
96	72	Calmwater	0	20	S	1.60	78.8	6.8
97	79	Calmwater	-5	20	S	0.99	48.0	79.2
98	76	Calmwater	-5	20	S	1.00	50.7	35.6
01	74	0.17x2.65	-5	20	S	0.43	21.5	9.7
02	76	0.17x2.65	0	20	S	1.33	69.8	7.6
03	85	0.17x2.65	-2	20	S	0.31	15.3	7.9
04	94	0.52x12.04	-2	20	S	0.21	10.3	6.8
05	97	0.52x12.04	0	20	S	0.20	10.0	4.0
06	107	0.52x12.04	-2	20	S	0.18	8.7	4.7
07	100	0.48x17.56	0	20	S	0.96	47.0	5.8
08	81	0.48x17.56	-2	20	M	0.91	42.7	36.4
09	75	0.48x17.56	-2	20	S	0.13	6.4	5.0
10	126	0.48x17.56	0	20	S	0.51	24.7	9.7
11	68	Calmwater	-2	20	M	1.21	59.3	25.6
12	51	Calmwater	-2	10	M	1.45	68.0	24.8
13	38	Calmwater	-2	10	S	1.11	54.7	7.9
14	40	Calmwater	-5	20	S	0.92	45.3	44.3
15	64	Calmwater	5	20	S	1.77	86.7	12.6
16	67	Calmwater	-5	20	S	1.50	74.0	56.9
17	79	Calmwater	0	20	S	1.80	88.7	11.2
18	73	Calmwater	0	7	S	1.17	95.8	14.4

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TABLE 144. (Continued)

Test no.	Slick thk. (mm)	Wave H x L (mxm)	Weir height (cm)(2)	Disc speed, (RPM)	Skimmer deploy-ment(3)	Oil rec. (m^3)	RE (%)	ORR m^3/hr
19	70	Calmwater	0	7	S	0.42	95.2	11.2
20	76	Calmwater	0	20	S	0.54	87.6	11.5
21	79	Calmwater	0	20	S	0.77	90.4	16.9
22	82	Calmwater	0	10	S	0.66	94.2	12.2
23	79	Calmwater	-2	20	S	1.16	57.4	96.8
24	63	Calmwater	0	10	S	1.78	86.7	55.4
25	43	Calmwater	8	10	S	0.87	92.9	9.7
26	39	Calmwater	0	20	S	1.06	88.4	10.4
27	33	Calmwater	-2	10	S	0.30	16.0	13.7
28	33	Calmwater	-2	20	S	0.37	34.7	33.1
29	41	0.48x17.56	0	10	S	0.11	5.3	6.5
30	47	Calmwater	0	10	S	0.28	13.5	4.7

1. Average viscosity: 1900 cSt.

2. With respect to still water line.

3. S = Skimmer head stationary during entire test.

   M = Skimmer head moved inside boomed area by operator for maximum oil pickup.

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TABLE 145. TEST RESULTS - FRAMO SKIMMER, MEDIUM OIL(1) (JO 42)

Test no.	Slick thk. (mm)	Wave H x L (mxm)	Weir height (cm)(2)	Disc speed, (RPM)	Skimmer deploy-ment(3)	Oil rec. (m^3)	RE (%)	ORR m^3/hr
31	73	Calmwater	0	10	S	0.71	91.9	15.8
32	65	Calmwater	0	20	S	0.66	82.6	19.8
33	65	Calmwater	-2	10	S	0.67	87.3	54.7
34	62	Calmwater	-2	20	S	0.24	47.3	19.4
35	63	Calmwater	-5	10	S	1.13	55.5	81.0
36	43	Calmwater	-5	20	S	0.77	38.0	92.5
37	122	Calmwater	-5	20	S	0.90	46.0	147.6
38	118	0.48x17.56	-5	20	S	0.83	41.4	75.2
39	122	0.48x17.56	-2	20	S	0.59	31.4	50.8
40	127	0.48x17.56	-2	20	M	1.10	53.4	77.8
41	133	Calmwater	-2	20	M	1.67	81.3	64.4
42	138	Calmwater	-5	20	M	1.17	56.7	191.9
43	143	Calmwater	8	20	M	0.65	80.7	49.7
44	151	Calmwater	8	10	S	0.48	88.8	14.8
45	135	Calmwater	-5	10	M	2.20	56.0	168.8
46	104	0.52x12.04	-2	20	S	0.25	12.4	15.1
47	106	0.52x12.04	0	20	S	0.17	8.0	6.8
48	100	Calmwater	0	20	S	1.05	51.3	54.0
49	94	0.5x12.04	-2	20	S	0.16	8.0	9.0
50	94	0.5x12.04	-2	20	M	0.31	15.0	19.1
51	93	0.5x12.04	0	10	S	0.18	9.0	9.0
52	97	0.5x12.04	8	10	S	0.21	17.0	5.8
53	97	0.17x2.65	-2	20	M	0.43	21.0	58.0
54	101	0.17x2.65	8	10	M	0.32	71.0	3.6
55	103	0.17x2.65	-2	20	M	0.49	25.0	68.0
57	6	Calmwater	8	10	S	ND	85.0	ND
58	94	0.17x2.65	0	10	S	0.73	36.0	23.8

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TABLE 145. (Continued)

Test no.	Slick thk. (mm)	Wave H x L (mxm)	Weir height (cm)(2)	Disc speed, (RPM)	Skimmer deploy-ment(3)	Oil rec. (m^3)	RE (%)	ORR m^3/hr
59	89	0.17x2.65	0	10	M	0.56	26.3	30.2
60	86	0.48x17.56	-2	20	M	0.33	17.0	22.3
61	85	0.48x17.56	-2	20	S	0.16	7.7	11.5
62	68	0.48x17.56	0	10	M	0.43	21.7	16.2
63	51	0.48x17.56	0	10	S	0.41	20.0	13.7
64	55	0.48x17.56	8	10	S	0.43	75.0	7.9
70	159	0.48x17.56	-5	20	S	0.99	48.7	91.4
71	156	0.48x17.56	-5	20	M	0.83	39.7	53.6
73	155	0.48x17.56	-5	20	M	1.28	49.3	177.5
74	158	0.48x17.56	-5	20	S	0.96	48.7	110.9
75	160	Calmwater	-5	20	S	1.30	65.7	146.5

1. Average viscosity: 480 cSt.

2. With respect to still water line.

3. S = Skimmer head stationary during entire test.

M = Skimmer head moved inside boomed area by operator for maximum oil pickup.

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TABLE 146. TEST RESULTS - WATER JET BOOM/SKIMMER TRANSITION DEVICE, HEAVY OIL (JO 42)

Test no.	Tow speed knots	Wave H x L (m x m)	No. jets(1)	Initial slick thk. (mm)	Water jet nozzle pressure skimmer (Kpa)	Water jet nozzle pressure boom (Kpa)	Slick width(2) (m)	Slick thickness(2) (m)
1	2-3	Calmwater	4	0.6	34	69	0.6	varied
2	2	Calmwater	4	1.3	34	69	0.75	25.8
3	3	Calmwater	4	1.3	34	69	0.75	25.0
4	3	Calmwater	0	1.3	0	0	1.75	6.1
5	2	Calmwater	0	1.3	0	0	2.75	6.0
6	3	Calmwater	0	1.2	0	0	1.25	13.9
7	1	0.5x12	0	1.4	0	0	1.25	5.7
8	1	0.5x12	4	1.3	69	69	1.5	12.9
9	2	0.5x12	4	1.2	34	69	1.75	5.6
10	2	0.5x12	0	0.7	0	0	3.00	2.9
11	3	0.5x12	0	0.6	0	0	3.00	2.5
12	3	0.5x12	4	0.5	34	69	2.00	3.4
13	1	0.5x12	2	0.6	69	0	1.25	7.6
14	2	0.5x12	2	0.5	34	69-0	2.50	3.1
15	3	0.5x12	2	0.7	34	0	3.00	3.6
16	3	0.5x12	2	0.6	69	117-0	3.00	2.8
17	1	Calmwater	2-0	0.7	34	0	1-1.5	6.4
18	1	0.5x12	6	0.7	34	69-21	0.75	13.6
19	2	0.5x12	6	0.6	34	69-21	1.75	2.8
20	3	0.5x12	6	0.6	34	69-21	2.25	2.6
21	2	Calmwater	6	0.8	34	69-21	1.00	11.8
22	3	Calmwater	6	0.6	34	69-343	1.00	8.8
23	2	0.5x12	8	0.5	34	69-21	2.50	3.1
24	3	0.5x12	8	0.7	34	69-21	3.00	3.1
25	2	Calmwater	8	0.6	34	69-21	1.00	8.5

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TABLE 146. (Continued)

Test no.	Tow speed knots	Wave H x L (m x m)	No. jets(1)	Initial slick thk. (mm)	Water jet nozzle pressure skimmer (Kpa)	Water jet nozzle pressure boom (Kpa)	Slick width(2) (m)	Slick thickness(2) (m)
26	3	Calmwater	8	0.6	34	69-21	1.25	6.6
27	1	1.0 HC	8	0.5	34-103	69	1.00	7.6
28	2	1.0 HC	8	0.6	34-103	69	2.00	2.7
29	3	1.0 HC	8	0.5	34	69	3.00	2.7
30	2	1.0 HC	8	0.5	207	310	1.00	8.2
31	1	1.0 HC	0	0.5	0	0	2.50	3.0
32	2	1.0 HC	0	0.5	0	0	2.50	3.2
33	3	1.0 HC	0	0.5	0	0	3.00	2.6
34	2	1.0 HC	6	0.5	34	69-346	2.00	4.2

1. The accounting system for the number of water jets in service was based upon starting with the jets on the skimmer (2 nozzles in service) and moving into the boom nozzles. The jets were always used in pairs. Example-- 6 nozzles in service meant all but the pair farthest from the skimmer were being used.

2. At skimmer bow.

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TABLE 147. TEST RESULTS - WATER JET BOOM/SKIMMER TRANSITION DEVICE, LIGHT OIL (JO 42)

Test no.	Tow speed knots	Wave H x L (m x m)	No. jets(1)	Initial slick thk. (mm)	Water jet nozzle pressure skimmer (Kpa)	Water jet nozzle pressure boom (Kpa)	Slick width(2) (m)	Slick thickness(2) (m)
40(3)	2	1.0 HC	0	0.6	0	0	3.00	3.0
41	2	1.0 HC	8	0.8	34	69	2.50	4.5
42	3	1.0 HC	0	0.6	0	0	3.25	2.3
43	3	1.0 HC	8	0.5	34	69	2.25	4.0
44	2	0.0	0	0.6	0	0	1.50	5.5
45	3	0.0	0	0.5	0	0	2.30	3.1
46	3	0.0	8	0.5	34	69	0.75	10.7
47	2	0.0	8	0.5	34	10-207	0.75	10.7
48(3)	2	1.0 HC	2	0.5	34	0	---	---
49	2	0.5x12	8	0.5	34	69	1.75	2.4
50	3	0.5x12	8	0.5	69	69	2.25	3.5
51	2	0.5x12	0	0.6	0	0	3.00	2.5
52	3	0.5x12	0	0.5	0	0	3.10	2.3
60(4)	2	0.0	0	0.6	0	0	2.00	4.2
61	2	0.0	8	0.6	34	69	0.75	11.2
62	3	0.0	0	0.4	0	0	2.75	2.5
62R	2	0.0	0	0.4	0	0	2.75	2.5
64	2	0.5x12	0	0.6	0	0	3.00	2.8
65	3	0.5x12	0	---	0	0	Tore up boom. Aborted.	

1. The accounting system for the number of water jets in service was based upon starting with the jets on the skimmer (2 nozzles in service) and moving into the boom nozzles. The jets were always used in pairs. Example-- 6 nozzles in service meant all but the pair farthest from the skimmer were being used.
2. At skimmer bow.
3. The forward splash of the skimmer affected the oil between the booms too much for the water jets to reduce the slick. This was the last harbor chop test.
4. Test numbers 60 through 65 were conducted using the flexible skirt to maintain the oil slick from the booms' exit to the skimmer.

3. Pump speed
4. Movement of the skimmer head about a horizontal plane
5. Pressure on the lifting cylinder that controls the wave response capability of the floating skimmer head

Device Modifications. No modifications were necessary to improve oil pickup performance. However, addition of a vertical elevation indicator for the weir lip position that could be seen from the control cab would assist the operator.

The manufacturer is considering certain modifications for future Framo skimmers including:

1. A smoother profile shape floatation collar to minimize wave slap and the consequent pushing of oil away from the rotating discs by short wavelength waves.

2. A new and sturdier wiper material.

3. A longer 17 m control arm with active hydraulic feedback control to allow faster heave response of the skimmer head for a wider range of wave periods.

JOB ORDER NO. 43 - LOCKHEED MISSILES AND SPACE CO., INC.

Dates	Not Tested	
Customer	Development Programs Material Lockheed Missiles & Space Co., Inc. 1111 Lockheed Way Sunnyvale, CA 94086	408-742-9045
Device	Lockheed R2003 Skimmer	

JOB ORDER NO. 45 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	Not Tested	
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817	201-321-6600
Device	Air Jet Boom Hydronautics, Inc. 7210 Pindell School Road Laurel, MD 20810	301-776-7454

JOB ORDER NO. 46 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates
18 April - 3 May 1978
20-30 June 1978
25-29 July 1978
8-12 August 1978
5-15 September 1978
25 September - 7 October 1978

Customer
Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Devices
Skim-Pak Skimmer
Douglas Engineering
5168 Brookside Lane
Concord, CA 94521 415-827-9040

EPM Model X-7 and X-8
Environmental Protection Machines, Ltd.
Rte. 2 Box 97
Estacada, OR 97023 503-630-6644

LPI-OSED Model 33 Skimmer
LPI Corporation
P.O. Box 113
Denville, NJ 07834 201-625-0002

Report
Breslin, M.K. and H.W. Lichte. Performance Testing of Selected Oil Skimmers Developed by Small Businesses. U.S. Environmental Protection Agency, Cincinnati, Ohio, 1980 (in preparation) (Ref. 10).

Description of Program

This EPA-sponsored program evaluated three newly developed skimmers selected because of promising technical concepts and provided the small business community with expensive test tank time to verify the expected high performance of each skimmer.

The first skimmer evaluated was the LPI-OSED, designed for nearshore coastal waters and harbors. Performance was significantly consistent and the simplicity of the skimmer design was such that it was used in other test programs during the season as a component of a skimming system. Several design modifications were made to the skimmer and a few OHMSETT testing techniques were enhanced as a result of testing.

The second skimmer, called the EPM skimmer, was smaller and sized for harbor use. This advancing skimmer had a unique articulated floating weir entrance, staged compartments, and a centrifugal pump. The owner/designer modified the pump and compartments as a result of the initial test series, and it was again tested to verify the performance efficiency.

The third in this test program was a small stationary skimmer, Skim-Pak, with a self-adjusting weir entrance designed to be used in ponds or dock areas. An EPA report is in preparation.

JOB ORDER NO. 47 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	3-12 April 1978	
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817	201-321-6600
Device	OHMSETT Test Fluid Distribution System	
Report	In-house capability report	

Description of Program

The study was designed to prove out the OHMSETT design and installation of a new distribution system for higher test oil delivery rates to advancing skimmers. Included also was a new system of oil heaters to increase the delivery rates of the heavy oils in cold weather. The goal was to accommodate new skimmers of higher recovery capacity to expand OHMSETT's testing capability. For further information, contact J.S. Farlow, Oil and Hazardous Materials Spills Branch, U.S. Environmental Protection Agency, Edison, New Jersey 08817.

JOB ORDER NO. 48 - FISHERIES AND ENVIRONMENT CANADA

Dates	10-18 October 1978	
Customer	Technology Evaluation and Transfer Unit Environment Emergency Branch Fisheries and Environment Canada Ontario, K1A 1C8, Canada	819-997-1788
Device	MI-30 and MI-3 Skimmers Morris Industries, Ltd. 1527 Columbia Street Vancouver, B.C. V7J 1A3, Canada	604-986-2189
Report	Solsberg, L.B.	

Description of Program

This program, sponsored by the Canadian Department of the Environment (Environment and Fisheries group) successfully evaluated two new skimmers designed and built in British Columbia. Both skimmers, one small and one large, were of the oleophilic disc concept. One advantage was the package/portability of these skimmers combined as self-contained systems. A side benefit of the program was the agreement

TABLE 148. TEST RESULTS - MORRIS SKIMMER CIRCO X HEAVY OIL (JO 48)

Test no.	Oil dist. volume (m^3)	Slick thk. (mm)	Waves (m x m)	RE (%)	TE (%)	ORR (m^3/hr)
1	0.09464	2.54	Calmwater	64.17	30.80	0.3
1R	0.09464	2.54	Calmwater	80.00	43.20	0.4
2	0.09464	2.54	Calmwater	74.68	47.20	0.5
3	0.47318	11.50	Calmwater	86.06	57.28	0.3
11	0.47318	11.50	Calmwater	84.40	70.56	1.7

TABLE 149. TEST RESULTS - MORRIS SKIMMER CIRCO MEDIUM OIL (JO 48)

Test no.	Oil dist. volume (m^3)	Slick thk. (mm)	Waves (m x m)	RE (%)	TE (%)	ORR (m^3/hr)
5	0.09464	2.54	Calmwater	89.11	72.00	0.9
5R	0.09464	2.54	Calmwater	94.33	93.20	1.0
6	0.09464	2.54	Calmwater	93.86	104.00	0.8
6R	0.09464	2.54	Calmwater	96.12	99.20	0.9
7	0.09464	2.54	0.29 HC	76.06	64.80	0.4
7R	0.09464	2.54	Calmwater	85.21	96.80	0.6
8	0.09464	2.54	0.29 HC	86.23	60.40	0.5
7R	0.09464	2.54	0.29 HC	85.21	96.80	0.6
8R	0.09464	2.54	0.29 HC	64.17	65.20	0.6
9	0.09464	2.54	Calmwater	94.14	102.80	1.0
10	0.09464	2.54	Calmwater	93.02	96.00	1.0
10R	0.09464	2.54	Calmwater	91.20	103.60	1.1
12	0.47318	11.50	Calmwater	68.37	85.76	2.0
12R	0.47318	11.50	Calmwater	68.96	79.44	1.0
13	0.47318	11.50	0.29 HC	57.43	65.84	1.2
13R	0.47318	11.50	0.29 HC	71.97	22.80	0.6
14	0.47318	11.50	Calmwater	94.80	86.08	2.8
14R	0.47318	11.50	Calmwater	92.92	91.28	4.2
14RR	0.47318	11.50	Calmwater	92.69	97.44	4.8
15	0.47318	11.50	0.50x12.04	83.98	78.00	3.1
15R	0.47318	11.50	0.50x12.04	84.43	96.32	3.6
16	0.47318	11.50	0.29 HC	85.30	88.64	2.9
16R	0.47318	11.50	0.29 HC	81.17	83.12	2.5
17	0.47318	11.50	Calmwater	94.92	100.08	4.2
18	0.47318	11.50	Calmwater	61.06	92.56	4.0
20	0.09464	2.54	0.29 HC	76.24	61.60	0.5
21	0.09464	2.54	0.19x5.46	88.10	94.80	0.9
22	0.09464	2.54	0.19x5.46	76.06	86.40	0.7
23	0.09464	2.54	0.50x12.04	84.95	70.00	0.7
24	0.09464	2.54	0.50x12.04	71.68	32.40	0.8
25	0.09464	2.54	Calmwater	93.12	92.00	1.0
26	0.09464	2.54	Calmwater	93.18	65.60	1.0

of OHMSETT data with the Canadian data taken in open water tests in Quebec City. For additional information, contact Mr. L.B. Solsberg, Head, Technology Evaluation and Transfer Unit, Environment Emergency Branch, Environment Canada, Ontario, Canada K1A 1C8.

JOB ORDER NO. 49 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 12-16 June 1978

Customer
Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Devices
Type 270 Sorbent Boom
3M Company
3M Center 53-4
St. Paul, MN 55101 612-733-3939

Heavy Duty Sorbent Boom
Conwed Corporation
332 Minnesota Street
St. Paul, MN 55101 612-222-3033

Petro-Trap Wringer
Petro-Trap
P.O. Box 157
Westport, MA 02790 617-675-7831

Reports

Smith, G.F. Performance Testing of Selected Sorbent Boom. EPA-600/7-78-219, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1978. 35 pp (Ref. 47).

Smith, G.F. Deployment Configuration Testing for Improved Selected Sorbent Boom Oil Containment. U.S. Environmental Protection Agency, Cincinnati, Ohio, 1980 (in press) (Ref. 48).

Description of Program

Three commercially available sorbent booms were evaluated by the EPA in various wave conditions, tow speeds, and slick thicknesses. Additional testing was performed to evaluate performance of the sorbent booms when deployed in different ways. Results indicated the maximum successful tow speed for each test condition, the feasibility of boom reuse, and oil/water capacity. A report (EPA-600/7-78-219) is available from NTIS. An EPA report, on additional work, is in preparation.

JOB ORDER NO. 50 - NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Dates 21-25 August 1978

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TABLE 150. 3M COMPANY-TYPE 270 SORBENT BOOM RESULTS (JO 49)

Test no.	Wave H (m)	Oil quantity m^3	Oil quantity % of capacity	Maximum no loss tow speed - V_c kts	Type of failure	Comments
1A	Calm	0	0	1.75	submergence	
2A	0.3 m HC	0	0	1.75	submergence	
3A	Calm	0.38	25	0.9	droplet shed	Turbulence caused by sorbent raft sections causes oil to form droplets and be swept under boom skirt.
4A	0.3 m HC	0.38	25	0.8	droplet shed	
5A	Calm	0.76	50	0.85	droplet shed	
6A	0.3 m HC	0.76	50	0.8	droplet shed	
7A	Calm	1.17	75	0.7	droplet shed	
8A	0.3 m HC	1.17	75	0.85	droplet shed	
9A	Calm	1.51	100	0.6	droplet shed	
10A	0.3 m HC	1.51	100	0.6	droplet shed	
11A	Calm	1.89	125	0.33	droplet shed	
12A	0.3 m HC	1.89	125	0.6	droplet shed	

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TABLE 151. 3M COMPANY-TYPE 270 SORBENT BOOM RESULTS (JO 49)

Test no.	Wave H (m)	Oil quantity m^3	Oil quantity % of capacity	Maximum no loss tow speed - V_c kts	Type of failure	Comments
1B	Calm	0	0	2.0	submergence	Ends of Goodrich boom submerged.
2B	0.3 m HC	0	0	2.0	splashover	
3B	Calm	0.38	25	0.45	slick under boom	
4B	0.3 m HC	0.38	25	0.4	droplet shed	
5B	Calm	0.76	50	0.5	slick under boom	
6B	0.3 m HC	0.76	50	0.5	droplet shed	Vortices formed at end of Goodrich boom throwing droplets under raft.
7B	Calm	1.17	75	0.55	slick under boom	
8B	0.3 m HC	1.17	75	0.55	droplet shed	
9B	Calm	1.51	100	0.55	slick under boom	
10B	0.3 m HC	1.51	100	0.55	droplet shed slick under boom	
11B	Calm	1.89	125	0.5	slick under boom	
12B	0.3 m HC	1.89	125	0.5	droplet shed slick under boom	

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TABLE 152. 3M COMPANY-TYPE 270 SORBENT BOOM RESULTS (JO 49)

Test no.	Wave H (m)	Oil quantity m^3	Oil quantity % of capacity	Maximum no loss tow speed - V_c kts	Type of failure	Comments
1C	Calm	0	0	over 2.0		
1C	0.3 m HC	0	0	over 2.0		
3C	Calm	0.38	25	0.9	slick under boom	
4C	0.3 m HC	0.38	25	0.3	droplet shed	Waves cause raft sections to hit each other producing turbulence and driving oil droplets under boom.
5C	Calm	0.76	50	0.65	slick under boom	
6C	0.3 m HC	0.76	50	0.3	droplet shed	
7C	Calm	1.17	75	0.65	slick under boom	
8C	0.3 m HC	1.17	75	0.2	droplet shed	
9C	Calm	1.51	100	0.8	slick under boom	
10C	0.3 m HC	1.51	100	0.2	droplet shed	
11C	Calm	1.89	125	0.75	slick under boom	
12C	0.3 m HC	1.89	125	0.25	droplet shed	

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TABLE 153. CONWED SORBENT BOOM RESULTS (JO 49)

Test no.	Wave H (m)	Oil quantity m^3	Oil quantity % of capacity	Maximum no loss tow speed - V_c kts	Type of failure	Comments
13A	Calm	---	---	1.6	raft driven under Goodrich Boom.	
14A	0.3 m HC	---	---	1.4	raft driven under Goodrich Boom.	
15A	Calm	0.27	25	0.85	droplet shed	
16A	0.3 m HC	0.27	25	0.7	droplet shed	
17A	Calm	0.54	50	0.7	droplet shed	
18A	0.3 m HC	0.54	50	0.7	droplet shed	
19A	Calm	0.81	75	0.7	droplet shed	
20A	0.3 m HC	0.81	75	0.7	droplet shed	
21A	Calm	1.08	100	0.7	droplet shed	
22A	0.3 m HC	1.08	100	0.6	droplet shed	
23A	Calm	1.35	25	0.7	droplet shed	
24A	0.3 m HC	1.35	25	0.7	droplet shed	

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TABLE 154. CONWED SORBENT BOOM RESULTS (JO 49)

Test no.	Wave H (m)	Oil quantity m^3	Oil quantity % of capacity	Maximum no loss tow speed - V_c kts	Type of failure	Comments
13B	Calm	---	---	1.75	ends of Goodrich Boom Submerge.	
14B	0.3 m HC	---	---	1.7	ends of Goodrich Boom Submerge.	
15B	Calm	0.38	25	0.7	droplet shed	
16B	0.3 m HC	0.38	25	0.5	droplet shed	
17B	Calm	0.76	50	0.65	droplet shed	
18B	0.3 m HC	0.76	50	0.5	droplet loss	
19B	Calm	1.14	75	0.7	droplet shed	
20B	0.3 m HC	1.14	75	0.5	droplet shed	
21B	Calm	1.51	100	0.6	droplet shed	
22B	0.3 m HC	1.51	100	0.3	droplet loss	
23B	Calm	1.89	125	0.7	droplet shed	
24B	0.3 m HC	1.89	125	0.3	droplet shed	

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TABLE 155. CONWED SORBENT BOOM RESULTS (JO 49)

Test no.	Wave H (m)	Oil quantity		Maximum no loss tow speed - V_c kts	Type of failure	Comments
		m^3	% of capacity			
13C	Calm	---	---	1.75	raft folds over	five layer raft.
14C	0.3 m HC	---	---	1.7	raft submarines	
15C	Calm	0.97	25	0.6	slick under boom	
16C	0.3 m HC	0.97	25	0.4	droplet shed	
17C	Calm	1.93	50	0.7	droplet shed	
18C	0.3 m HC	1.93	50	0.4	droplet shed	
19C	Calm	2.89	75	0.5	slick under boom	
20C	0.3 m HC	2.89	75	0.5	droplet shed	
21C	Calm	3.86	100	---	boom sections totally saturated after test 20C.	
22C	0.3 m HC	3.86	100	---	boom sections totally saturated after test 20C.	
23C	Calm	4.83	125	---	boom sections totally saturated after test 20C.	
24C	0.3 m HC	4.83	125	---	boom sections totally saturated after test 20C.	
25C	Calm	---	---	1.75	raft folds over	two layer raft.
26C	0.3 m HC	---	---	1.7	raft submarines	two layer raft.
27C	Calm	0.62	25	0.2	slick under boom	failure due to poor rigging - rerigged, two layer raft.
28C	Calm	0.72	25	0.4	slick under boom	three layer raft.
29C	Calm	0.86	25	0.5	slick under boom	four layer raft.

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Customer	U.S. Department of Commerce National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite Service F.O.B. No. 4 Room 0124 Suitland, MD 20233	301-763-7054
Device	Filter Wedge Spectometer Closed-Circuit TV System Barnes PRT-S Radiometer NOAA, Office of Research Washington, DC 20233	301-763-1847
Report	Hovis, W.A. and J.S. Knoll. Optical Measurements of Crude Oil Samples Under Simulated Conditions. NOAA TM-NESS 105, U.S. Department of Commerce, Rockville, Maryland 20852, 1979 (Refs. 26, 27).	

Description of Program

The National Oceanic and Atmospheric Administration's National Environmental Satellite Service sponsored an OHMSETT program to evaluate a new concept of a satellite deployable, oil detector system. The testing at OHMSETT consisted of using the oil detector mounted on our bridge system to monitor various selected crude oils aging in containment cells and exposed to the local weather over a week's time. Oil detector experiments have been performed at OHMSETT by other agencies in the past with dock-mounted systems, but not with the sophistication of satellite electronics. One new side benefit and experience of this program was our successful capability to respond to deploying real crude oils in place of paraffinic of naphthenic based refined oils with less dangerous properties. For additional information, contact Mr. John Knoll, National Oceanic and Atmospheric Administration, National Environmental Satellite Service, Washington, D.C. 20233.

Conclusions

The reflectance of the crude oil samples tested under simulated aging conditions changed insignificantly with time. The reflected signal levels that would be seen from a satellite viewing sunlit oil on the ocean surface are small, but possibly detectable in the 0.4 to 1.1 μm region. From 1.1 to 2.4 μm, the reflected signal levels are so low that there appears to be no rationale for looking for oil spills in that spectral region.

Crude oil floating on the ocean surface will be extremely difficult to detect when the water is deep and reasonably clean. In cases where the water has higher reflectance, such as an area where there is a large concentration of suspended sediments or organic growth, oil might be detected as a dark patch against a lighter background. This would also apply over shallows where bottom reflectance would provide a bright background.

Searching for oil slicks in glint patterns may be of some value from aircraft where angles of view can be controlled. But in the case of spacecraft, where view angles are dictated by orbital geometry, it is doubtful that practical use could be made of this technique. The Coastal Zone Color Scanner (CZCS) on Nimbus-7 has a tilt mechanism for avoiding glint that could be commanded to look into the glint, but glint would not cover the entire image, only a fraction of the 1600-km swath. It would be rare that an oil spill would be viewed in that fraction of the swath. In any event, earlier U-2 imagery and photos have shown many dark streaks in sun glint that cannot be attributed to any known oil spill.

From our measurements, temperature differences offer the most promise for oil spill detection by optical sensors from satellites, but are limited by the need for clear skies to provide both the opportunity to observe the ocean surface, and sunlight to produce the thermal contrast.

JOB ORDER NO. 51 - Not assigned.

JOB ORDER NO. 52 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 31 July - 4 August 1978
14-18 August 1978

Customer Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Device LPI Model 33 Skimmer
LPI Corporation
P.O. Box 113
Denville, NJ 07834 201-625-0002

Report Foster, D.M., S.H. Schwartz, and G.F. Smith. A Statistical Evaluation of the LPI-OSED Skimmer, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1979 (in press) (Ref. 22).

Description of Program

This study sponsored by the EPA was important to the growth of OHMSETT testing technology. The goal was to determine the cost effectiveness of repeating certain tests to gain statistical and mathematical knowledge of test data. The problem of sample size is classic to every testing facility and is generally traded off with dollars, time schedules, and test variables. The study produced baseline data, presentable to customers for their use in estimating test goals. An EPA report is in press.

JOB ORDER NO. 53 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates Not Tested

Customer Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Device
Permafloat Boom, 18 PFX
B.F. Goodrich
430 S. Main Street
Cohasset, MA 02025 617-383-6000

JOB ORDER NO. 54 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates
28 August - 1 September 1978
16-27 November 1978

Customer
Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Device
Catamaran Mounted Water Jet Oil Herder
OHMSETT
P.O. Box 117
Leonardo, NJ 07737 201-291-0680

Report
Breslin, M.K. The Use of Coherent Water Jets to Control Oil Spills. U.S. Environmental Protection Agency, Cincinnati, Ohio, 1980 (in preparation) (Ref. 8).

Description of Program

The water jet booms, designed by the OHMSETT staff, were mounted on the OHMSETT catamaran to test design construction and performance prior to ZRV tests scheduled for October 1979. Design modifications were based upon the results of these tests. The concept proved feasible, simple and reliable; the construction of prototypes for the Coast Guard was subsequently undertaken. The water jet booms concentrated oil slicks in calm waters and in wave conditions at every tow speed from zero to 6 kts. A second half of the program tested a discontinuous oil diversionary boom consisting of water jets mounted on individual floats strung together and towed down the tank. The tests proved that the concept was feasible in all wave conditions and tow speeds up to six knots. The concept was tested as a possible alternative to the use of continuous fabric booms in oil spill recovery situations where ship traffic would make it difficult to close off a river completely using a fabric boom. The discontinuous water jet booms would allow ships to pass between the floats without damaging the equipment. The system can also be used where currents are too high to permit use of a fabric boom. An EPA report is in preparation.

SECTION 9

TESTS PERFORMED IN 1979

JOB ORDER NO. 44 - U.S. COAST GUARD

Dates 19 September - 12 October 1979

Customer Office of Research and Development
U.S. Coast Guard
G-DMT-4/TP54
Washington, DC 20593 202-426-1023

Device Shell Zero Relative Velocity (ZRV) Skimmer
Shell Development Co.
E-1340 West Hollow Research
P.O. Box 1380
Houston, TX 77001 713-493-7094

Air Jet Boom
Hydronautics, Inc.
7210 Pindell School Road
Laurel, MD 20810 301-776-7454

Water Jet Boom
OHMSETT
P.O. Box 117
Leonardo, NJ 07737 201-291-0680

Report Breslin, M.K. Performance Tests of High Speed ZRV Oil Skimmer, U.S. Department of Transportation, U.S. Coast Guard, Office of Research and Development, CG-D-42-80, June 1980 (Ref. 3a, 7).

Description of Program

These tests climaxed a four-year development program by the USCG of a high speed oil recovery device. The skimmer was designed and developed by Shell Development Company of Houston, TX and the vessel was designed by Allan McClure Associates of Houston, TX. Since the skimmer weighed over 29,000 kg and was towed at 6 knots, it produced the largest kinetic energy ever developed in tests at OHMSETT. The device recovered oil at every tow speed up to 6 knots in the largest regular and harbor chop waves producible at OHMSETT. A set of conveyor-like sorbent belts was processed through a wringer system on the skimmer at approximately the same speed that the skimmer was being towed forward; when these belts are in contact with the water, there is no relative motion between the belt and the water; therefore the name

Zero Relative Velocity (ZRV). Two oil slick converging booms were tested with the skimmer. One was an air jet boom, developed for the EPA by Hydronautics, Inc. of Laurel, Maryland and the other was the water jet boom, developed for the EPA by OHMSETT operating personnel. The air jet boom was tested only in calm water as per the designer's request, while the water jet boom was tested in many wave conditions and calm water. The results showed that the water jet boom was the better performer. The Coast Guard has since provided for permanent mounting of the water jet booms on the ZRV skimmer. A U.S. Coast Guard 16 mm film entitled, "USCG Zero Relative Velocity (ZRV) Oil Skimmer" is available from the Research and Development Branch, U.S. Coast Guard, Washington, DC.

Conclusions

The USCG ZRV proved itself able to continuously recover and offload a substantial amount of oil in every sea state (calm water to a 0.7 m harbor chop) and at every tow speed (1 to 6 knots) produced at OHMSETT during this test program. The type of oil (heavy, medium and light) and oil slick thickness affected performance with heavy oil and a thick slick being the most difficult to recover. The maximum performance of the device recovering a 3 mm oil slick is shown in Table 156.

TABLE 156. MAXIMUM PERFORMANCE (3 mm OIL SLICK) FOR ALL OILS (JO 44)

	2 knots			4 knots			6 knots		
	TE (%)	RE (%)	ORR (m^3/hr)	TE (%)	RE (%)	ORR (m^3/hr)	TE (%)	RE (%)	ORR (m^3/hr)
Calm	92	85	27.9	100	70	63.1	95	64	87.2
0.5 m HC	93	51	28.6	94	54	55	81	56	84
0.7 m HC	N/A	N/A	N/A	72	60	43.4	N/A	N/A	N/A
0.4 m x 9.4 m wave	72	41	21.8	76	48	45.2	62	47	55.2

The maximum ORR was 107 m^3/hr (Test No. 152) RE = 54%, TE = 53%; the slick thickness was 10.4 mm.

The tests were determined to be reliable indicators of device performance based upon a Box Behnken analysis of the data performed by the U.S. Coast Guard.

At OHMSETT, the skimmer was assembled easily within a few hours using a 70-ton crane and three men. The lifting apparatus which accompanies the skimmer greatly assists assembly and lifting the entire device. Assembly could have been accomplished much faster if an experienced crew was employed.

There were very few problems with the machinery or drive engines. The prototype system is, however, slightly underpowered since the fire pumps, offloading pumps and belt drives cannot be used to their maximums simultaneously.

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TABLE 157. TOW TEST DATA USCG ZRV SKIMMER, CIRCO MEDIUM OIL (JO 44)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
SD10	4.00	2.9	Calm	48.0	49.0	28.2	4.00	137	Discrete sampler is onboard the ZRV catch-all trough is mounted beneath the forward rollers.
SD11	4.00	2.9	Calm	47	70.7	40.2	4.00	137	Hole in catch-all trough dripping fluid in the center of the device to split the slick into the belts.
SD12	4.00	3.0	Calm	47	76.4	45	4.00	137	Bar in rear wringer assembly removed, belt was losing fluid onto squeezed belt when it touched the bar.
SD13	4.00	3.0	Calm	48	74.1	43.4	4.00	137	Lowered rear drums 216 mm.
SD14	4.00	3.0	Calm	50	88.1	52.7	4.00	137	Replicate of SD13.
SD15	4.00	3.0	Calm	51	75.4	44.1	4.00	137	First precharge test, some oil was spilled over into the catch-all trough, drums are lowered.
SD16	4.00	3.0	Calm	48	90.8	53.8	4.00	137	Same as SD15. Ran oil distribution 35 sec instead of 45 sec, precharged with oil hose again. Stbd belt dripping water at front.

(Continued)

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TABLE 157. (CONTINUED)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
SD17	4.00	3.1	Calm	60	91.3	55.9	4.00	137	Collection barrels overflowed about 11 liters of fluid, port belt appears to be squeezed better than the stbd belt, used precharge manifold.
SD18	4.00	3.1	Calm	64	82.5	50.2	4.00	137	Good test, 98% encounter.
SD19	4.00	3.2	Calm	68	98.0	61.1	4.5	137	Lower sump drain closed, +½ kt ZRV on the belts.
SD20	4.00	2.5	Calm	65	74.6	36.1	3.5	137	Lower sump drain closed -½ kt ZRV on the belts.
SD21	4.00	3.1	Calm	64	99.9	61.3	5.00	137	+1 kt ZRV test
SD22	4.00	3.1	Calm	65	103.8	63.1	3.00	137	-1 kt ZRV test
SD24	4.00	3.3	Calm	56	76.6	48.6	2.50	137	-1½ kt ZRV test
1	3.50	3.1	2.06 HC	56	84.4	42	3.50	137	Belt hold down device contacted waves at times.
2	3.50	3.0	2.06 HC	58	74.3	38.2	3.50	137	Belt hold down device struck waves.

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TABLE 157. (CONTINUED)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
3	2.50	4.9	0.65, 38.0$^{(b)}$	62	86.7	52.2	4.00	137	Bridge in slow down mode so the scheduled 4 kt, ZRV test became a 2 kt, + 1.5 kt test, belt hold down device contacted waves lightly.
4	3.00	3.3	Calm	54	88.2	43.2	2.50	137	Center water jet working well.
5	3.50	3.1	Calm	70	90.6	49.1	3.00	137	Slick contacting inboard 85% of the belts.
6	3.50	3.1	1.04 HC	49	74.8	39.1	3.00	137	Center water jet rubber hose swung with movement of the vessel making zig zag in the oil.
7	1.00	1.1	Calm	35	82.3	4.1	0.75	137	Slick in the center 75% of the belts for the beginning ¼ of the test.
8	1.00	3.0	Calm	54	88.4	11.1	0.75	137	Slick predominantly on the stbd side of the vessel for ½ of the test.
9	1.00	5.1	Calm	58	77.4	17.5	0.75	137	Good test, some oil going down between the belts and the hulls.
10	2.00	1.3	Calm	52	73.4	9.1	1.50	137	Three small water jets on the bow of the skimmer, they are working well.

(Continued)

TABLE 157. (CONTINUED)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
11	4.00	3.2	1.57 HC	54	68.4	42.5	3.50	137	99% encounter, stbd. belt ran to stbd on rear drum
12	4.00	3.1	Calm	57	84.5	51.1	3.50	137	Looked okay underwater.
13	2.00	5.2	Calm	90	54.6	27.9	1.50	137	100% encounter with the heavy slick.
14	2.00	3.1	Calm	85	91.5	27.7	1.50	137	Wind blowing center water jet off to side a little.
15	3.00	3.1	Calm	58	82.5	38.2	2.50	137	Even slick, good test.
16	4.00	1.1	Calm	64	111.3	23.4	3.50	137	Oil distributed past normal cut off point.
16R	4.00	0.8	Calm	43	108.0	16.6	3.50	137	Good test.
17	4.00	3.0	Calm	55	70.4	41.8	3.50	137	Good test.
18-20									5 & 6 kt shakedown tests.
21	6.00	1.2	Calm	44	107.8	39.1	5.50	137	First 6 kt test - all went well.
22	4.00	4.7	Calm	58	59.7	54.7	3.50	137	Good test.
23									6 kt shakedown test - no oil.
24									6 kt shakedown test no oil - vessel squatted about 25.4 cm under tow.

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TABLE 157. (CONTINUED)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
25	6.00	2.8	Calm	48	50.9	42	5.50	137	Even slick across vessel, belts rolling straight down into the water off the forward rollers.
26	6.00	3.0	Calm	46	53.8	48.2	5.50	57	Good test, but belts contacted the rear brace somewhat.
27	6.00	5.0	Calm	54	55.0	80.9	5.50	57	Even slick across belts.
28	5.00	3.0	Calm	72	61.7	45.9	4.50	57	Good tests, belts did not strike the brace.
29	4.00	4.8	Calm	54	66.4	61.3	4.50	137	Three forward water jets working well, good test.
30	4.00	3.2	Calm	54	75.2	47.9	3.50	137	Good test, lost some oil from beneath the port belt, stbd. belt was red.
31	4.00	3.2	Calm	64	75.0	47.2	3.00	137	Good test, even slick.
32	4.00	2.8	Calm	66	78.9	44.1	3.00	137	Duplicate of 31, very little escaped between or down the sides of the belts.
33	4.00	2.8	Calm	70	88.3	48.4	4.00	137	Good test.
34	4.00	3.1	1.57 HC	50	67.9	41.3	3.50	137	Tied belt hold down device back to prevent it hitting the waves.
35	2.00	1.2	1.57 HC	41	104.0	12	1.50	137	Belts draping into the water, slick is not even across the belts due to waves, belts blotted up oil.

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TABLE 157. (CONTINUED)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
36	4.00	3.0	1.57 HC	47	61.7	36.1	3.50	137	Good test, belt hold down device did not strike the waves.
37	6.00	1.1	1.57 HC	36	109.2	36.1	5.50	137	Belt hold down device occasionally struck the waves.
38	4.00	3.1	1.57 HC	49	65.5	39.3	3.50	137	Some belt hold down device contact with waves.
39	2.00	5.1	1.57 HC	57	82.3	41.3	1.50	137	Some contact between belt hold down device and waves, surge of hulls converged the slick into the center 75% of the belts.
40	4.00	3.3	1.04 HC	48	84.4	54.1	3.50	137	Good test, occasional slap of belts against the rear brace.
41	6.00	4.9	1.57 HC	43	41.8	59.5	5.50	60	Belt hold down device slapped waves occasionally.
42	4.00	3.7	2.26 HC	49	61.8	44.7	3.50	56	Great deal of surging of hulls and wave contact with belt hold device.
43	4.00	3.4	Calm	50	83.0	55	5.00	137	OK test.

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TABLE 157. (CONTINUED)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
110	6.00	5.0	1.18, 30.8	41	39.6	56.6	5.50	63	Belt hold down device struck waves, hull surges caused oil slick disturbance.
111	6.00	1.0	1.18, 30.8	43	111.2	33.4	5.50	63	Interference with belt hold down device and hull surges.
112	2.00	1.0	1.18, 30.8	19	97.1	9.5	1.50	63	Wave reflection from vessel rolled forward into the slick and moving it to the center of the device.
113	4.00	3.0	1.18, 30.8	35	33.5	20	3.50	63	Belt hold down device is entraining oil.
114	4.00	3.1	1.18, 30.8	45	71.8	43.6	3.50	63	Repeat of 113, belt hold down device struck waves, oil appeared to adhere to belts better on this test.
115	2.00	5.0	1.18, 30.8	75	58.0	28.2	1.50	63	Surge moved slick to center - saturated inboard areas of belts.
116	4.00	3.0	1.18, 30.8	48	76.0	45	3.50	63	Some slick entrainment due to belt hold down device and hull surge, but a good test.

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(4-76)

TABLE 157. (CONTINUED)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
117	6.00	3.2	Calm	39	39.3	37	6.00	57	Fluid coming from belts at forward rollers, belts scraped during the run.
118	6.00	3.2	Calm	64	53.7	50.6	6.00	57	Belts scraped again.
119	6.00	3.0	Calm	37	72.6	64	5.50	60	Bow rollers extended, belt speed reduced, still scraped a little.
120	6.00	3.0	Calm	48	70.1	62.5	5.50	66	Bow rollers extended, no scraping, port belt lost oil behind, stbd belt lost fluid at the forward rollers.
121	6.00	3.2	Calm	57	88.7	84	5.50	66	Repeat of 120 - Good test.
122	5.00	3.0	Calm	45	73.5	54.3	4.50	66	Fluid from forward rollers dripping on the slick.
123	4.00	3.0	Calm	50	92.0	53.8	5.50	137	Belts draping over the front, good test, east wind blew most of the slick to the stbd side for ½ of the test, hull surge causing oil to move to the center, bow is pitching 0.75 m.

(Continued)

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TABLE 157. (CONTINUED)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
Air Jet Boom Tests #128 through 141 - Slick width --- 5.0 m wide.									
128	2.00	1.8	Calm	32	27.6	8.9	1.50	137	Air streams moved a good deal of oil into the center and down between the belts, the inner ¼ of each belt was saturated.
129	2.00	1.8	Calm	35	38.0	53	2.00	137	Air pressure reduced but oil is still going into the center and down between the belts, some oil is being lost beneath the Air Jet boom.
130	3.00	1.7	Calm	26	45.6	92	3.00	137	Air pressure varied from 2.8 kg/cm^2 down.
131	4.00	1.7	Calm	42	41.4	114	3.50	137	Stbd air jet boom appears stronger than port, a rolling wave is helping to herd the slick.
132	4.00	1.7	Calm	33	50.4	132	3.50	137	Larger water jet in the center of the device, air from booms disturbed smaller jet, inner ¼ of belts saturated, but no oil escaping between them, booms moved closer to the bow of the skimmer.

(Continued)

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TABLE 157. (CONTINUED)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
133	4.00	1.7	Calm	38	35.5	99	3.50	137	Oil saturating inner 1/3 of belts.
134	4.00	1.8	Calm	52	55.4	157	3.50	137	Good test, slight bow wave being made by aluminum connection helping to move oil.
135	4.00	1.7	Calm	42	46.6	123	3.50	137	Good test, tow points holding cable for air jet boom are producing the rolling wave seen previously.
136									Aborted, belts would not start.
137	6.00	1.7	Calm	30	52.0	205	5.50	137	Some oil passed beneath the air jet boom.
138	6.00	1.6	Calm	12	29.9	114	5.50	66	Belt extender out.
139	4.00	1.8	Calm	29	13.9	39	3.50	53	Rags in ports of air jet to get higher flow from upstream ports.
140	4.00	1.7	Calm	24	48.9	128	3.50	53	Wake from air jet boom causing rolling wave which moves oil into the water jets, belt scraped rear brace because belt hold down device was not engaged.

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TABLE 157. (CONTINUED)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
141	4.00	1.7	Calm	31	56.9	151	3.50	53	Tow points and aluminum connection pieces producing rolling wakes. Wind blowing oil into port air jet.
142	6.00	3.1	Calm	24	54.3	48.4	5.50	65	Uneven slick, stbd belt speed fell from 5.5 to 5 knots at the end of the test.
143	6.00	3.1	Calm	27	56.3	222	5.50	65	Narrative not available.
144	6.00	3.1	Calm	23	69.4	288	5.50	65	Good test.
145	4.00	3.1	Calm	60	85.6	231	2.50	137	Slow belt speed caused headwave to develop in front of the belts, this pushed oil to the center of the device.
146	4.00	3.2	2.26 HC	34	49.5	130	3.50	65	OK test.
Water Jet Tests #154 through 168 - Slick Width was 5.45 m									
154	2.00	1.4	Calm	73	79.4	92	1.50	53	Water Jet test #154 through 168 - slick width was 5.45 m, all oil appears to be directed inside the skimmer's center section.

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TABLE 157. (CONTINUED)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
155	4.00	1.5	Calm	31	60.3	161	3.50	53	Some oil is missing outside the bows.
156	6.00	1.6	Calm	23	33.8	137	5.50	65	Bow waves by the hulls were brownish-pink indicating the oil was not moved far enough to reach the center section of the skimmer.
157	2.00	1.5	1.57 HC	38	55.5	74	1.50	59	Water jet pressure was reduced from 2.8 kg/cm^2 to 2.1 kg/cm^2. The higher pressure was pushing the oil too far into the center.
158	4.00	1.5	2.26 HC	24	56.5	150	3.50	59	Most of the oil was moved into the center section of the skimmer.
159	4.00	1.5	1.57 HC	28	59.4	157	3.50	59	Water jet pressure at 5.6 kg/cm^2 (maximum)
160	4.00	1.5	Calm	34	61.5	157	3.50	59	Narrative not available.
161									Presoak test to determine how much oil could be extracted from the belts if no oil was distributed.
162	6.00	1.5	1.57 HC	34	53.2	205	5.50	59	Good test.

(Continued)

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TABLE 157. (CONTINUED)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
163	6.00	1.5	1.57 HC	22	40.0	164	5.50	64	OK.
164	6.00	1.5	1.57 HC	34	53.9	210	5.50	64	OK, repeat of 163.
165	4.00	1.6	2.26 HC	28	63.1	41.3	3.50	64	Good test.
166	4.00	1.6	Calm	36	57.2	160	3.50	137	Narrative not available.
167	2.00	1.5	Calm	29	69.4	84	1.50	137	The skimmer fire pump supplied the water to the water jets.
168	4.00	1.5	Calm	33	64.4	167	3.50	137	Two water jets on each boom were used.
169	3.00	10.0	Calm	67	55.5	351	4.00	137	Heavy slick test with a fast belt to try to obtain the maximum oil recovery rate.
170	6.00	3.1	1.57 HC	56	81.1	326	5.50	64	Good test.

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TABLE 158. TOW TEST DATA USCG ZRV SKIMMER, CIRCO X HEAVY OIL (JO 44)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR m^3/hr	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
44	2.00	3.2	Calm	48	51.3	68	1.50	137	Lost oil outside of hulls and between belts and hulls, slick was uneven.
45	2.00	3.1	Calm	69	77.9	104	1.50	137	Repeat of 44 to saturate belts with heavy oil, underwater view of slick is good.
46	2.00	3.1	Calm	75	86.8	114	1.50	137	Repeat of test 44. Slick was even, water jets worked well.
47	3.00	2.9	Calm	53	96.0	181	2.50	137	Even slick, good test.
48	2.00	4.8	Calm	78	65.0	132	1.50	137	OK test.
49	4.00	1.2	Calm	36	121.4	128	3.50	137	Good test.
50	4.00	3.4	Calm	59	90.9	262	3.50	137	Oil remained in a good tight slick, bridge water jets were almost not needed.
51	4.00	4.9	Calm	61	66.9	281	3.50	137	Good test.
52	4.00	5.2	Calm	56	73.3	326	4.50	137	Port belt received a little more oil than the stbd belt.
53	4.00	3.1	2.26 HC	60	72.0	191	4.50	137	Large harbor chop caused severe pitch, belt hold down device struck the waves.

(Continued)

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TABLE 158. (CONTINUED)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
54	2.00	3.1	1.57 HC	49	59.5	17.3	1.50	137	Uneven slick due to wave action. Little entrainment.
55	2.00	3.1	1.57 HC	51	93.4	28.6	2.50	137	Uneven slick, some entrainment of oil, hull surging is forcing oil towards the center of the device.
56	2.00	3.1	1.57 HC	47	80.6	24.5	1.50	152	Uneven slick shifted from port to stbd belt, belt hold down device tied back.
57	6.00	3.1	Calm	52	95.1	87.2	5.50	145	Belt hold down device tied back. OK test.
58	6.00	3.5	Calm	50	50.9	51.8	5.50	145	Vessel had slight yaw to port.
59	6.00	3.1	1.57 HC	52	65.1	59.7	5.50	145	Belt hitting the rear cross brace periodically.
60	4.00	3.0	1.57 HC	137	93.7	55	3.50	145	Starboard belt struck rear brace periodically.
61	4.00	3.2	1.57 HC	36	62.0	38.6	3.50	152	OK test, forward rollers extended to take up belt slack.
62	4.00	1.1	1.57 HC	46	140.8	32	3.50	152	Good test with almost no oil left behind.

(Continued)

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TABLE 158. (CONTINUED)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
63	4.00	5.0	1.57 HC	47	45.5	44.3	3.50	152	Starboard belt looks splotchy, compared to port, inboard areas of belts coated well due to hulls surging and moving slick to the center.
64	6.00	3.2	1.57 HC	46	64.9	71.6	5.50	152	Good test.
65	6.00	3.0	1.57 HC	49	61.4	54.3	6.00	152	Good test, water jets working well.
66	4.00	3.0	1.04 HC	43	76.8	45.4	3.50	152	Small harbor chop does not entrain very much oil.
67	4.00	3.1	Calm	68	95.6	57.2	3.50	152	Some oil was washing on top of the belts as it passed between them and the hulls, OK test.
68	4.00	3.1	Calm	48	92.3	56.3	4.00	152	Good test.
69	4.00	3.2	Calm	50	87.4	53.6	4.00	152	Good test.
70	4.00	3.0	Calm	70	68.5	40.7	3.50	152	Belts appear a little splotchy, first test after the weekend.
71	4.00	3.1	Calm	63	82.2	50	3.50	152	Repeat of 70 - good test.
72	4.00	3.0	1.57 HC	45	74.3	43.8	3.50	152	99% encounter - OK test.
73	4.00	3.0	2.26 HC	33	52.4	30.9	3.50	152	Hull surging is driving oil towards the center of the device.

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TABLE 158. (CONTINUED)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
124	2.00	3.1	1.18, 30.8	41	64.9	20	1.50	62	East wind moved the slick over to the starboard side a bit for half the test run.
125	6.00	3.2	1.18, 30.8	47	40.7	37.9	5.50	62	Hull surge causing oil to move to the center, bow is pitching 0.75 m.
126	4.00	5.0	1.18, 30.8	72	64.3	62.2	3.50	62	Hull surge concentrating oil into the center.
127	4.00	1.0	1.18, 30.8	44	197.6	40.2	3.50	62	OK test.

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TABLE 159. TOW TEST DATA USCG ZRV SKIMMER, CIRCO 4X LIGHT OIL (JO 44)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
74	4.00	2.9	Calm	43	72.9	41.6	3.50	152	Good slick, not much entrainment of the light oil.
75	4.00	2.5	Calm	42	64.7	31.6	3.50	152	100% encounter - Good test.
76									Aborted--ran out of oil during the test.
77	4.00	4.0	Calm	38	50.4	39.1	3.50	152	Heavier slick in the center.
78	4.00	3.4	Calm	42	55.9	36.6	3.50	152	Repeat of 77, slick better due to change in width of oil distribution manifold.
79	2.00	3-4.7[(a)]	Calm	152	77.1	34.1	2.50	152	Slick was varied to observe losses at the rear of the device, port belt lost a bit more oil than the stbd.
80	2.00	3-5.3	Calm	55	65.0	32.5	2.50	152	Slick varied to observe progressive losses from belts at the rear drums, oil slick driven completely to port during middle of test.
81	2.00	3-6.3	Calm	44	70.9	39.5	2.50	152	Repeat of 80 with an even slick. Rear drums filmed, port belt lost a slight bit more oil, but not much.

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TABLE 159. (Continued)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
82	2.00	3.1	Calm	30	51.5	15.9	2.00	152	Underwater filming of the belts by diver under tow, such filming probably detracted from skimmer performance.
83	2.00	3.7	Calm	26	33.3	11.6	2.00	152	Underwater filming.
84	2.00	5.1	Calm	28	40.2	19.1	3.50	152	Underwater filming.
85	2.00	1.2	Calm	68	354.5	40.9	1.50	152	Vessel not cleared of oil after presoak.
86	2.00	1.0	Calm	66	261.6	25.9	1.50	152	Oil probably still very heavy on the belts.
87	2.00	3.3	Calm	58	55.5	17.7	2.50	137	Prewet 379 liters prior to test.
88	4.00	1.3	Calm	35	127.9	33.4	3.50	137	Wind is blowing the slick from side to side, it is raining.
89	2.00	1.1	Calm	29	82.6	8.9	1.50	137	Slick down the inboard portion of the belts, raining.
90	2.00	5.1	Calm	73	61.0	36	1.50	137	Good slick, OK test.
91	3.00	3.1	Calm	44	97.8	45	2.50	137	Cross winds blowing center water jet making zig zag in slick.
92	4.00	3.0	Calm	36	86.6	51.8	3.50	137	OK test.

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TABLE 159. (Continued)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
93	4.00	4.8	Calm	47	56.3	51.8	3.50	137	Started tests without slick herding jets on, but recovered okay, 97% encounter.
94	4.00	4.8	Calm	45	55.9	51.8	4.50	137	Starboard belt mistracked and was shutdown.
95	4.00	5.2	Calm	45	94.3	94.5	4.50	137	Repeat of 94, all looked good.
96	4.00	3.1	Calm	33	65.6	39.7	4.50	137	Good test.
97	6.00	1.2	Calm	22	76.7	28.2	5.50	137	Good test.
98	6.00	3.1	Calm	34	83.1	75	5.50	137	Good test, a good deal of excess fluid coming off from the front rollers into the trough overflowing it slightly.
99	6.00	5.2	Calm	46	70.3	106.5	5.50	137	Good test, fluid being lost from port belt at forward rollers.
100	5.00	3.1	Calm	44	89.9	67.7	4.50	137	OK test.
101	4.00	1.0	1.18, 30.8	38	131.6	25	3.50	137	Hull surge drives oil to the center of the device, belts are blotting up the oil well, belts struck rear brace.
102	4.00	1.0	1.18, 30.8	30	88.5	18.2	3.50	57	Extended forward rollers, some scraping of stbd belt on rear brace.

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TABLE 159. (Continued)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
103	4.00	1.0	1.18, 30.8	27	89.9	18.2	3.50	152	Extended rollers again, still slight scraping.
104	2.00	3.1	1.18, 30.8	31	72.0	21.6	1.50	152	Slight scraping, but good test.
105	4.00	1.0	1.18, 30.8	20	99.1	20.4	3.50	65	Forward rollers out further, belts did not leave the rear drums.
106	4.00	1.1	1.18, 30.8	35	101.3	20.7	3.50	63	Front rollers brought in, no scraping, belt hold down device is tied back.
107	2.00	3.2	1.18, 30.8	40	65.8	20.2	1.50	63	Pitching drives oil to the center, belts are saturated on their inboard halves.
108	6.00	3.1	1.18, 30.8	32	61.6	55	5.50	63	Belt hold down device is tied back but is contacting the waves, pitching very pronounced.
109	4.00	4.8	1.18, 30.8	37	71.5	67	3.50	63	Belt hold down device struck a little, but it was a good test.
147	2.00	3.2	1.57 HC	26	22.3	6.8	1.50	137	Wave coming forward from device is rolling into the slick, belt scraped on rear brace.

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TABLE 159. (Continued)

Test no.	Tow spd. (kts)	Slick thk. (mm)	Wave H (m)	RE %	TE %	ORR (m^3/hr)	Belt spd. (kts)	Fwd Roller Ext. (cm)	Comments
148	2.00	3.0	1.57 HC	41	79.1	23	1.50	152	Forward rollers extended, repeat of 147, good test.
149	4.00	1.0	1.57 HC	19	131.5	26	3.50	152	
150	6.00	3.2	1.57 HC	36	72.4	65.9	5.50	152	OK test.
151	2.00	3.0	Calm	25	61.1	17.7	1.50	137	OK test, loss from the belts looked to be equal.
152	4.00	10.4	Calm	54	53.3	106.7	5.00	137	Good test.
153	4.00	4.5	1.57 HC	43	76.8	68.1	3.50	137	OK test.

The skimmer is capable of high performance oil recovery at every tow speed tested. Waves decrease performance due to vessel motion and rolling waves produced from wave-to-vessel contact.

The skimmer obtained better results in heavier oils in 3 mm slicks but in 5 mm slicks a greater amount of light oil was sorbed by the belts.

The device appeared to perform better when the belts were run slack. The best belt speed was about 0.5 to 1.0 knot faster than ZRV. The precharging of the belts prior to an oil test did not appreciably affect device performance.

The lowering of the rear drums did not have an effect on device performance. This also indicates that slight variations in trim of the vessel would not adversely affect performance.

The freeboard of the center section should be increased to allow more clearance during pitching and heaving. If the belt contacted the underside of the device during a test the shock would shake oil from the belt and entrain it beyond the reach of the belt.

The belt hold-down device contacted the oil slick and entrained oil beyond the reach of the belts during wave tests and six knot calm water tests. Fluid which was scraped from the belt contained a greater percentage of oil than the determined RE of the test. The scrapers appeared to remove much of the oil from the belt while the wringer appeared to remove much of the water. Bars, braces and rollers which contacted the oil laden composite belts stripped oil and water from them. This could dump recovered oil back on the water or onto a recently wrung portion of the belt and thus affect oil recovery performance.

A hydrocarbon sniffer test indicated there was no explosive vapor concentrations in the oil skimmer under the test conditions.

Of the two oil herding devices tested, the water jet out performed the air jet boom at every tow speed and could also perform in wave conditions while the air jet boom, as tested, was limited to calm water.

Wave response tests indicated the vessel to be sea kindly and a stable craft.

JOB ORDER NO. 55 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	7-28 June 1979	
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817	201-321-6600
Device	Soviet Oil/Debris Skimmer Black Sea Central Design-Construction Bureau 15-A Lostochkin Street Odessa, USSR	

Report Lichte, H.W. Performance Testing of the Soviet Oil/Debris Skimmer, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1980 (in preparation) (Ref. 30).

Description of Program

Planning and testing of this device was performed under the auspices of a joint US-USSR committee on oil pollution, with EPA sponsoring the program. The language barriers, large size and weight of the Soviet Skimmer, as well as the transportation of the skimmer from the USSR to OHMSETT and back to the USSR provided the major challenges during this test. The skimmer incorporates a unique design for high performance in and around harbor areas. The OHMSETT performance testing confirmed the Soviet published numbers and most of the salient features while the skimmer operated for twenty days without significant breakdown. Large quantities of water were handled without degrading oil collection performance using combinations of sharp crested weirs, broad crested weirs, centrifugal pumps, siphons, air eductors, gravity separators and filters. Forty eight metric tons of oil were recovered (averaging 3.8 MT per hour) in a large variety of oil and sea conditions and operating modes. Both stationary and advancing modes of skimming were tested using a two-man operating crew. An EPA report is in preparation. (Ref. 28)

Conclusions

The Soviet Oil/Debris Skimmer, Model 2550/4 was a good performer to its design conditions. The unique application of various weirs into one system, mobility, the efficient use of energy, the incorporation of series oil/water separation, the propulsion system, and using high oil/water flow conditions suggest the skimmer best of its class in harbor operations. The oil collection performance was near the design specifications and proved better in the heavy than light as expected due to entrainment. The high throughput efficiencies in the normal advancing and stationary modes was commendable.

The centrifugal pump used in the gravity separation system was effective to move oily water. The second onboard pump, a vortex fire/ballast system had a significantly less capacity. Future modifications of the design should address the incorporation of a positive displacement pump somewhere in the circuit. The two-man operation of the vessel was difficult, whereas one is needed on the bow while the second divided his time between the wheel house and pump controls. Skimming oil while underway requires an additional man.

Future testing of the skimmer should address, in more detail, the efficiency of the coke filter system, use of the gill door in the skimming mode, and larger oil volume performance tests requiring significant quantities of oil in the port-side storage.

TABLE 160. SOVIET SKIMMER PERFORMANCE RESULTS - CIRCO HEAVY OIL (JO 55)

Test no.	Tow speed (knots)	Oil dist. rate (m^3/hr)	Slick thk. (mm)	Waves H x L (m x m)	RE (%)	TE (%)	ORR (m^3/hr)
30	1.0	10.7	2.66	Calm	81.5	90.5	3.6
31	1.0	10.7	2.66	Calm	81.5	88.7	3.2
32	1.0	10.4	2.60	Calm	81.5	90.6	4.1
33	1.0	21.5	5.36	Calm	61.5	59.0	4.7
34	1.5	37.1	6.16	Calm	61.5	67.1	5.3
35	2.0	50.0	6.23	Calm	61.5	66.8	5.3
36	2.0	0	0.00	Calm	0.0	0.0	0.0
37	2.0	58.3	7.26	0.36x6.95	81.0	25.5	2.8
38	2.0	55.6	6.92	0.36x6.95	81.0	26.7	2.8
39	1.5	47.0	7.81	0.36x6.95	81.0	23.7	2.8
40	2.0	56.2	7.00	Calm	82.3	80.9	10.5
41	2.0	58.1	7.24	Calm	82.3	78.1	9.7
42	2.0	56.9	7.09	Calm	82.3	79.8	12.4
43	0.0	11.8	0.00	Calm	94.4	86.6	6.1
44	2.0	21.2	2.63	0.36x6.95	82.6	58.4	4.6
45	2.0	21.5	2.68	Calm	82.6	58.4	4.6
46	2.0	21.3	2.66	0.36x6.95	82.6	58.0	3.2
47	2.0	11.8	2.64	Calm	82.6	58.0	3.2
48	2.0	28.0	1.01	Calm	79.3	79.6	6.7
49	2.0	28.3	1.27	Calm	79.3	78.8	4.2
50	2.0	28.5	1.02	Calm	79.3	78.4	4.2
51A	2.0	0.0	0.00	0.40x6.95	0.0	0.0	0.0
51B	2.0	28.6	1.28	0.40x6.95	63.8	25.6	1.7
52	2.0	28.5	1.02	0.40x6.95	63.8	25.7	1.5
53	2.0	28.6	1.28	0.40x6.95	63.8	25.6	1.5
54	1.5	21.9	1.01	0.40x6.95	85.9	30.7	1.9
55	1.5	20.4	1.22	0.40x6.95	85.9	32.9	2.4
56	1.5	20.6	0.98	0.40x6.95	85.9	32.8	3.4

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TABLE 160. (Continued)

Test no.	Tow speed (knots)	Oil dist. rate (m^3/hr)	Slick thk. (mm)	Waves H x L (m x m)	RE (%)	TE (%)	ORR (m^3/hr)
57	2.0	87.8	3.94	Calm	83.3	70.3	8.4
58	2.0	94.6	4.24	Calm	83.3	65.3	8.4
59	2.0	0.0	0.00	0.20x11.61	0.0	0.0	0.0
60	1.5	79.3	4.74	0.20x11.61	72.0	36.7	5.1
61	1.5	79.4	4.75	0.20x11.61	72.0	36.6	6.6
62	1.5	81.9	4.90	0.20x11.61	72.0	28.4	5.8
63	1.0	22.6	5.62	0.20x11.61	73.7	56.8	4.8
64	1.0	21.6	5.38	0.20x11.61	73.7	59.4	4.8
65	1.0	21.7	5.41	0.20x11.61	73.7	59.0	5.9
66	2.0	9.1	1.13	Calm	64.8	110.0	3.6
67	2.0	9.1	1.13	Calm	64.8	146.7	6.7
68	2.0	9.1	1.13	Calm	64.8	146.7	6.7
69	1.0	9.1	2.26	0.20x11.61	70.0	38.3	2.1
70	1.0	9.1	2.26	0.20x11.61	70.0	46.0	2.1
71	1.0	9.1	2.26	0.20x11.61	70.0	46.0	1.9
72	1.0	16.1	4.00	0.40x1.52	72.1	64.0	5.1
73	1.0	16.1	4.00	0.40x1.52	72.1	64.0	5.1
74	1.0	15.7	3.92	0.40x1.52	72.1	65.2	4.4
75	2.0	32.3	4.02	0.40x1.52	77.5	58.2	6.3
76	2.0	30.6	3.81	0.40x1.52	77.5	61.4	8.1
77	2.0	30.9	3.85	0.40x1.52	77.5	60.8	5.9
78	1.5	26.1	4.34	0.40x1.52	73.3	51.3	4.9
79	1.5	26.4	4.38	0.40x1.52	73.3	50.9	4.9
80	1.5	26.4	4.38	0.40x1.52	73.3	50.9	5.4
81	1.0	26.7	6.66	0.69 HC	72.0	33.1	4.8
82	1.0	26.7	6.66	0.69 HC	72.0	33.1	5.3
83	1.0	27.0	6.72	0.69 HC	72.0	32.8	6.6
84	2.0	33.2	4.13	0.69 HC	48.9	15.5	3.1
85	2.0	33.0	4.11	0.69 HC	48.9	15.6	2.2

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TABLE 161. SOVIET SKIMMER PERFORMANCE RESULTS - CIRCO LIGHT OIL (JO 55)

Test no.	Tow speed (knots)	Oil dist. rate (m^3/hr)	Slick thk. (mm)	Waves H x L (m x m)	RE (%)	TE (%)	ORR (m^3/hr)
86	2.0	34.5	4.30	Calm	50.9	79.1	5.1
87	2.0	32.5	4.06	Calm	50.9	83.9	5.1
88	2.0	33.9	4.23	Calm	50.9	80.5	5.1
89	2.5	44.9	4.47	Calm	33.3	45.6	2.9
90	2.5	41.7	4.15	Calm	33.3	49.1	3.1
91	2.5	42.9	4.28	Calm	33.3	47.6	4.1
92	0.0	11.8	0.00	Calm	51.3	101.9	4.1
93	1.0	16.3	4.06	Calm	50.7	88.5	4.3
94	1.0	16.4	4.09	Calm	50.7	87.7	8.6
95	1.0	16.1	4.02	Calm	50.7	89.3	5.4
96	1.0	16.1	4.02	0.20 HC	37.6	52.0	3.0
97	1.0	16.2	4.15	0.20 HC	37.6	51.7	5.0
98	1.0	16.1	.02	0.20 HC	37.6	52.0	5.0
99	2.0	34.1	4.24	0.20 HC	45.9	59.0	5.0
100	2.0	32.4	4.04	0.20HC	45.9	62.0	6.0
101	2.0	32.4	4.04	0.20 HC	45.9	62.0	6.0
102	2.0	145	18.07	Calm	36.4	63.8	4.7
103	2.0	33.5	4.17	0.40x1.52	56.6	73.3	5.7
104	2.0	33.0	4.11	0.40x1.52	56.6	74.3	7.3
105	2.0	33.0	4.11	0.40x1.52	56.6	74.3	6.1
106	1.5	26.1	4.34	0.40x6.95	40.4	30.8	3.2
107	1.5	23.8	3.96	0.40x6.95	40.4	33.7	3.6
108	1.5	24.8	4.11	0.40x6.95	40.4	32.5	3.6
109	2.0	33.6	4.31	0.40x6.95	43.0	29.5	4.2
110	2.0	32.5	4.06	0.40x6.95	43.0	30.5	4.2
111	2.0	48.6	6.06	0.40x6.95	43.0	30.6	3.7
112	1.5	25.3	4.21	0.20x11.61	39.9	26.3	2.7

(Continued)

TABLE 161. (Continued)

Test no.	Tow speed (knots)	Oil dist. rate (m^3/hr)	Slick thk. (mm)	Waves H x L (m x m)	RE (%)	TE (%)	ORR (m^3/hr)
113	1.5	25.6	4.24	0.20x11.61	39.9	26.1	3.8
114	1.5	25.1	4.17	0.20x11.61	39.9	26.6	2.2
115	2.0	32.4	4.04	0.20x11.61	42.1	35.1	2.8
116	2.0	32.4	4.04	0.20x11.61	42.1	35.1	2.4
117	2.0	32.4	4.04	0.20x11.61	42.1	35.1	2.8
118	1.5	24.9	4.13	0.20x11.61	41.0	47.9	3.6
119	1.5	25.5	4.23	0.20x11.61	41.0	42.1	3.1
120	1.5	24.9	4.13	0.20x11.61	41.0	57.5	3.6
121	1.0	17	4.24	Calm	52.6	81.6	6.4
122	1.0	16.1	4.02	Calm	52.6	86.2	10.4
123	1.0	16.2	4.04	Calm	52.6	85.8	4.9
124	2.0	32.9	4.09	Calm	59.0	85.3	5.3
125	2.0	33.8	4.21	Calm	59.0	83.0	5.3
126	2.0	33.8	4.21	Calm	59.0	83.0	5.3
127	1.0	22.7	5.66	0.69 HC	19.9	8.0	1.2

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TABLE 162. SOVIET SKIMMER BASELINE TESTS (JO 55)

Test no.	Weir angle (%)	Ballast level (mm)	Engine speed (rpm)	Bow box (dm)	Stern box (dm)	Main duct flow (m^3/s)	Vert duct flow (m^3/s)
1	55	400	1000	NA	NA	0.41/0.46	0.06/0.18
2	60	400	1200	2.5	5	0.55/0.62	0.09/0.47
3	6	550	1400	NA	NA	0.60/0.66	0.50/0.58
4	60/50	550	1600	2	-5	0.66/0/80	0.44/0.58
5	45	550	1800	NA	NA	0.78/0.88	0.44/0.58
6	70	550	1000	3	-5	0.46/0.58	0.51/0.29
7	65	550	1200	3	-6	0.57/0.60	0.12/0.18
8	60	550	1400	-3	-5	0.72/0.78	0.12/0.18
9	65	550	1600	3	-6	0.76/0.76	0.29/0.70
10	60/50	550	1800	-3/1	-5/4	0.87/0.93	0.18/0.26
11	70/65	550	1800	4	-5	0.90/0.95	0.29/0.73
12	65/60	340	1600	3	5	0.78/0.80	0.50/0.53
13	60	340	1400	3	5	0.72/0.75	0.44/0.44
14	70	340	1200	3	4.5	0.60/0.64	0.23/0.44
15	70	340	1000	3	5	0.49/0.57	0.00/0.00
16	70	50	1000	3.5	-6	0.36/0.41	0.03/0.15
17	60	50	1200	3/3	5/5.5	0.57/0.62	0.00/0.20
18	60	50	1400	3	4.5	0.70/0.76	0.00/0.00
19	65/55	50	1600	3/1.5	5.5/4.5	0.73/0.87	0.00/0.18
19R	60/55	50	1600	3/2	5.5/5	0.73/0.79	0.09/0.29
20	50/53	50	1820	NA	NA	0.84/0.90	0.15/0.29
20R	50/53	50	1800	2/2	5/5.5	0.83/0.92	0.00/0.29
21	80/80	50	1000	4.5/4.5	6.5/6.5	0.41/0.55	0.00/0.00

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TABLE 162. (Continued) (JO 55)

Test no.	Weir angle (%)	Ballast level (mm)	Engine speed (rpm)	Bow box (dm)	Stern box (dm)	Main duct flow (m^3/s)	Vert duct flow (m^3/s)
21R	75/75	50	1000	4/4	5/5.5	0.51/0.62	0.00/0.00
22	70/70	50	1200	4/3.5	-5/5	0.59/0.73	0.00/0.00
23	70/60	50	1400	3.5/2.5	-5/-5	0.67/0.75	0.00/0.00
24	60/60	50	1600	2.5/3	4.5/4.5	0.76/0.82	0.00/0.00
25	65/55	50	1800	3/1.5	5/4	0.80/0.90	0.00/0.06
27	80	50	1400	NA	NA	0.66/0.93	0.00/0.00
28	85	50	1600	6/5	8.5/7	0.36/0.79	0.23/0.29
29	70/75	50	1800	4/4	3.5/3.5	0.93/1.04	0/0

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JOB ORDER NO. 56 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates
23 May - 1 June 1979
2-6 July 1979
12-13 September 1979

Customer
Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817
201-321-6600

Device
Catamaran Mounted Water Jet Herder
OHMSETT
P.O. Box 117
Leonardo, NJ 07737
201-291-0680

Report
Breslin, M.K. The Use of Coherent Water Jets to Control Oil Spills U.S. Environmental Protection Agency, Cincinnati, Ohio, 1980 (in preparation) (Ref. 8).

Description of Program:

The waterjet booms, designed by the OHMSETT staff, were mounted on the OHMSETT catamaran to test construction and performance prior to ZRV tests scheduled for October 1979. Design modifications were based upon the results of these tests. The concept proved feasible, simple and reliable; the construction of prototypes for the Coast Guard was subsequently undertaken. The water jet booms concentrated oil slicks in calm water and in wave conditions at every tow speed from zero to six knots.

A second half of the program tested a discontinuous oil diversionary boom consisting of water jets mounted on individual floats strung together and towed down the tank. The tests proved that the concept was feasible in all wave conditions and tow speeds up to six knots. The concept was tested as a possible alternative to the use of continuous fabric booms in oil spill recovery situations where ship traffic would make it difficult to close off a river completely using a fabric boom. The discontinuous water jet booms would allow ships to pass between the floats without damaging the equipment. The system can also be used where currents are too high to permit use of a fabric boom. An EPA report is in preparation. (Also see Job Order 54).

Conclusions

Vertically directed water jets proved capable of moving and holding an oil slick on the surface of water at all speeds tested (up to six knots) and in all wave conditions (up to 1.2 m wave height).

Despite the turbulence produced by a water jet when impacting a water's surface, a relatively high current and thick oil slick need be present before a substantial amount of oil can penetrate the crater produced by the jet and be entrained beneath the water stream. Very little oil entrainment was noticed even with the thickest slick (5 mm) tested at a tow speed of six knots.

The rolling waves produced by the passage of the water jet helped to move the oil initially. Some oil is entrained by the rolling bow and following waves produced by the jet, but the oil remains near the surface and rises quickly as it is moved with the currents produced by the rising bubbles.

When converging an oil slick, sufficient time must be allowed after the water jet passes an area to enable the surface current to fully develop and to move the oil slick before an oil skimmer can most effectively encounter the thickened slick. This could be anywhere from 3 to 60 seconds depending upon the desired convergence.

Thick oil slicks were not moved as easily as thin oil slicks.

The best performance of the converging water jet arrangement was obtained using two and three pairs of jets at a high pressure. At six knots a 4.5 m wide, 1.1 mm thick slick was converged to a 0.6 m wide, 8.1 mm thick slick in 10 seconds. These results are most probably not the maximum attainable using three pairs of jets. Since the first pair of jets were positioned wide and forward of the oil slick their full effectiveness was not utilized.

From the single jet tests it was found that the most effective performance occurred at the highest pressures with the larger nozzle at low tow speeds and at a nozzle exit height of 0.4 to 1.0 m above the water's surface.

The water jet system performed well and was free from major breakdowns throughout the test program. However, a slight burr on the inside of a nozzle could cause the water stream to lose coherence and spray more. The penetrating and air entraining power of the jet is thus diminished and subsequently oil slick movement performance decreases. Pipes and nozzles should be checked for imperfections; rocks and other foreign matter should be removed from the hoses before assembly.

The use of water jets mounted on individual floats to control an oil slick is feasible; however, there are problems which must be solved before the concept becomes practical for field use.

The construction of water jet floats can be done using plywood, standard piping material, and suitable floatation (e.g., inflatable bags, steel drums, logs). Water jet floats allow waves normally reflected by conventional fabric booms to pass while retaining an oil slick.

Maintaining the individual floats in a predesigned orientation and formation while towing proved difficult. Floats drifted behind one another due to the fluid drag. Before proper counterweights were used to counter the forward pitching force of the supply hose, the floats would occasionally submerge at their bow and flip over.

Water jet booms can be successfully incorporated onto a moving oil skimmer to converge a wide, thin slick into a narrow, thick one for easier oil recovery.

Vertically directed jets proved to be the best all-wave performers. Angled jets performed slightly better than the vertical jets in calm water, but performed erratically in wave situations. The point of impact of a stream from angled jets and the distance between the nozzle exit and the point of impact changed drastically when the long booms on which the jets were mounted reacted to the catamaran's pitch and heave in waves.

Using the electric motor driven fire pump available on the OHMSETT main bridge, the best performance at different tow speeds by water jets on the 7.25 m wide slick is presented below:

TABLE 163. WATER JETS BEST PERFORMANCE (JO 56)

Tow speed (kts)	Nozzle size (cm)	Pressure (kPa)	Water jet angle in/fwd. degrees	Wave cond.	Orig. slick width (m)	Final slick width (m)	Slick movement (m)
2	2.1	205.94	0/0	calm	6.1	1.7	4.4
4	2.1	549.19	20/0	calm	4.2	1.1	3.2
6	2.1	588.42	10/45	calm	6.1	2.9	3.2

Note: Not all nozzle sizes were tested at all pressures and tow speeds.

A satisfactory boom length for a water jet off the bow of a skimmer appears to be from 6 to 12 m. A longer water jet extension improves performance in calm water; however, any pitching and heaving of the vessel is amplified by the long boom. If the boom is too long, vessel movement can cause the water jet to be raised high above the water's surface and plunged into the water regularly. Such action renders the water jets ineffective.

The stationary tests revealed that some oil is entrained by a passing water jet, but that almost all of the oil slick remains on the surface. Oil that is entrained is carried away from the water jet impact point as it rises to the surface. The angled jets appeared to entrain more oil.

A pair of water jets can be expected to essentially double the sweeping width of the U.S. Coast Guard's ZRV skimmer from 2.7 to 5.4 m at speeds up to 4 kts. To perform as well at 6 kts a longer boom would be required.

Based upon the computer literature searches, these theoretical analyses appear to be the first of their kind and thus a number of individual theories had to be combined to define the water jet phenomenon. This necessitated some assumptions and approximations to combine the formally separate theories and to simplify the

TABLE 164. CONTROL TESTS, CALM WATER SLICK CONVERGENCE TESTS (JO 56)

Test no.	Speed (kts)	Slick thk. @ 0 m (mm)	Slick width @15 m (m)	Slick width @30 m (m)	% Expan @15 m	% Expan @30 m	Slick thk. @15 m (mm)	Slick thk. @30 m (mm)
31	2	1.21	4.8	6.06	7	33	1.13	0.91
32	4	1.20	4.8	5.75	7	27	1.13	0.95
33	6	0.95	4.8	5.15	7	13	0.89	0.84
34	2	2.40	5.75	6.66	27	47	1.89	1.64
35	4	2.16	5.45	6.06	20	33	1.80	1.62
36	6	2.16			CAMERA MALFUNCTION			
36R	6	2.21	5.15	5.45	13	17	1.95	1.84
37	2	3.24	6.06	7.27	33	60	2.43	2.03
38	4	3.29	6.06	6.96	33	53	2.47	2.15
39	6	3.09	6.06	6.36	33	40	2.32	2.21
39R	6	3.12	6.06	6.36	33	40	2.34	2.23

TABLE 165. CONTROL TESTS, 0.6 m HC SLICK CONVERGENCE TESTS (JO 56)

Test no.	Speed (kts)	Slick thk. @ 0 m (mm)	Slick width @15 m (m)	Slick width @30 m (m)	% Expan @15 m	% Expan @30 m	Slick thk. @15 m (mm)	Slick thk. @30 m (mm)
40	2	1.27	5.15	5.75	13	27	1.12	1.00
41	4	1.02	4.8	5.15	7	13	0.96	0.90
42	6	0.97	4.8	4.8	7	7	0.91	0.91
43	2	2.04	5.15	5.45	13	20	1.80	1.70
44	4	1.62	4.54	6.66	0	47	1.62	1.10
45	6	2.11	6.06	5.45	33	20	1.58	1.76
46	2	3.23	6.66	6.06	47	33	2.20	2.42
47	4	3.18	5.75	6.66	27	47	2.51	2.17
48	6	3.62	4.8	4.8	7	7	3.39	3.39

TABLE 166. WATER JET TESTS, CALM WATER SLICK CONVERGENCE TESTS (JO 56)

Test no.	Speed (kts)	Slick thk. @0 m (mm)	Slick width @15 m (m)	Slick width @30 m (m)	Slick thk. @15 m (mm)	Slick thk. @15 m (mm)	Number of nozzles	Water press. (kPa)
1	2	1.14	3.63	2.72	1.43	1.90	2	70
2	2	1.19	1.5	2.12	3.57	2.55	4	70
3	2	1.09	1.51	1.81	3.27	2.73	6	70
4	4	1.09	3.63	3.33	1.36	1.49	2	140
5	4	1.04	2.72	1.51	1.73	3.12	4	140
6	4	1.15	2.42	0.90	2.16	5.75	6	140
7	6	1.16	3.63	2.72	1.45	1.93	2	280
8	6	1.08	2.42	0.60	2.03	8.10	4	280
9	6	1.01	2.72	0.90	1.68	5.05	6	280
10	6	1.11	3.03	2.72	1.67	1.85	2	560
11	4	1.03	1.21	0.90	3.86	5.15	4	560
14	2	0.92	0.90	2.72	4.60	1.53	6	420
16	2	1.11	3.03	2.72	1.67	1.85	2	140

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TABLE 167. WATER JET TESTS, 0.6 m HC SLICK CONVERGENCE TESTS (JO 56)

Test no.	Speed (kts)	Slick thk. @0 m (mm)	Slick width @15 m (m)	Slick width @30 m (m)	Slick thk. @15 m (mm)	Slick thk. @15 m (mm)	Number of nozzles	Water press. (kPa)
16	2	1.13	3.63	3.03	1.41	1.70	2	70
17	2	1.13	1.81	1.81	2.82	2.82	4	70
18	2	1.16	2.12	1.51	2.49	3.48	6	70
19	4	1.08	3.93	3.63	1.25	1.35	2	140
20	4	1.17	2.42	1.51	2.19	3.51	4	140
21	4	1.17	2.42	1.21	2.19	4.39	6	140
22	6	0.95	3.93	3.33	1.09	1.30	2	280
23	6	1.23	2.72	0.90	2.05	6.15	4	280
24	6	1.16	2.42	1.81	2.18	2.89	6	280

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TABLE 168. WATER JET TESTS, CALM WATER SLICK CONVERGENCE TESTS (JO 56)

Test no.	Speed (kts)	Slick thk. @0 m (mm)	Slick width @15 m (m)	Slick width @30 m (m)	Slick thk. @15 m (mm)	Slick thk. @15 m (mm)	Number of nozzles	Water press. (kPa)
49	4	1.05	2.72	1.81	1.5	2.63	6	70
50	4	1.08	2.12	0.90	2.31	5.40	6	280
41	4	1.05	1.51	0.90	3.15	5.25	6	420
52	4	2.26	3.03	1.81	3.39	5.65	6	70
53	4	2.21	2.42	1.51	4.14	6.63	6	280
55	4	2.26	2.12	1.51	4.84	6.78	6	420

TABLE 169. WATER JET TESTS, 1.2 m HC SLICK CONVERGENCE TESTS (JO 56)

Test no.	Speed (kts)	Slick thk. @0 m (mm)	Slick width @15 m (m)	Slick width @30 m (m)	Slick thk. @15 m (mm)	Slick thk. @30 m (mm)	Number of nozzles	Water press. (kPa)
56	4	1.25	1.81	1.51	3.13	3.75	6	560
57	4	6.23	2.42	2.72	11.68	10.38	4	280
58	4	6.23	2.42	2.12	11.68	13.35	4	560

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TABLE 170. SINGLE JET TEST RESULTS SLICK PARTING (JO 56)

Test no.	Tow speed (kts)	Nozzle ID* (cm)	Slick thk. (mm)	Water press (kPa)	Wave H (m)	Elapsed Time (sec) 15	30	45	60
						Slick Movement (m)			
7	2	2.1	0.9	140	Calm	2.4	2.8	3.1	3.4
8	2	2.1	1.2	280	Calm	2.7	3.4	3.8	4.0
9	2	2.1	1.2	560	Calm	3.4	4.2	4.5	4.8
10	2	2.1	1.2	0	Calm	7.6	8.0	8.5	8.8
11	4	2.1	0.8	140	Calm	2.0	2.4	2.4	2.6
12	4	2.1	1.0	280	Calm	2.2	2.6	2.9	3.1
13	4	2.1	1.1	560	Calm	2.2	3.0	3.8	4.5
14	6	2.1	1.0	140	Calm	1.3	1.8	2.3	2.5
15	6	2.1	1.0	280	Calm	1.8	2.3	2.7	2.9
16	6	2.1	1.0	560	Calm	2.1	2.6	3.0	3.5
17	2	2.7	1.4	140	Calm	2.7	3.5	3.8	4.1
18	2	2.7	1.2	280	Calm	2.8	3.6	4.2	4.5
19	2	2.7	1.2	560	Calm	4.2	5.1	5.4	5.7
20	4	2.7	1.2	140	Calm	1.8	2.6	3.0	3.2
21	4	2.7	1.2	280	Calm	2.4	2.9	3.6	4.5
22	4	2.7	1.2	560	Calm	2.7	3.5	4.4	5.1
23	6	2.7	1.0	140	Calm	2.0	2.6	2.9	3.2
24	6	2.7	0.9	280	Calm	2.1	2.8	3.5	3.9
25	6	2.7	1.1	560	Calm	2.7	3.2	3.8	3.9
26	2	2.7	2.7	280	Calm	3.0	4.5	5.0	5.4
27	4	2.7	4.8	280	Calm				3.5
28	6	2.7	3.3	280	Calm				3.4
29	2	2.7	1.4	560		3.6	3.9	4.8	5.8
30	4	2.7	1.1	560		2.4	3.6	4.2	4.7
31	6	2.7	0.7	560		2.3	3.3	3.6	4.2

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TABLE 170. (Continued)

Test no.	Tow speed (kts)	Nozzle ID* (cm)	Slick thk. (mm)	Water press (kPa)	Wave H (m)	Elapsed Time (sec) 15	30	45	60
						Slick Movement (m)			
32	2	2.7	1.3	280	1.2HC	2.1	3.0	3.9	4.5
33	4	2.7	0.7	560	1.2HC	3.0	4.2	5.2	4.9
34	4	2.7	1.1	280	1.2HC	2.1	3.3	3.5	3.7
35	2	2.7	1.3	560	1.2HC				6.1
36	6	2.7	0.9	280	1.2HC				2.7
37	6	2.7	0.9	560	1.2HC				4.6
26R	2	2.7	3.5	280	Calm				4.2
21R	4	2.7	1.1	280	Calm				3.6
22R	4	2.7	0.9	560	Calm				4.8

*ID = inner dimension

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TABLE 171. WATER JET HEIGHT EFFECTS SLICK PARTING TESTS (JO 56)

Test no .	Tow speed (kts)	Nozzle ID (cm)	Height of exit above water (m)	Slick thk. (mm)	Water press. (kPa)	Wave (m)	Elapsed Time (sec) 10	20	30	40
							Slick Movement (m)			
1	4	2.1	0.6	3	560	Calm	2.4	3.2	3.9	4.4
2	6	2.1	0.6	3	560	Calm	2.3	2.8	3.4	3.6
3	6	2.1	1.2	3	560	Calm	1.6	2.2	2.5	2.8
4	4	2.1	1.2	3	560	Calm	2.0	3.0	3.3	3.5
5	4 to 6	Observation run				Calm				
6	4 to 6	Observation run				Calm				
7	4	2.1	0.3	3	560	Calm	2.7	2.9	3.4	3.6
8	6	2.1	0.3	3	560	Calm	2.6	2.6	2.8	3.1
9*	4	2.1	-0.6	3	210	Calm	1.7	1.7	1.9	2.0

*Test run with 210 kPa of pressurized air being fed through a 2.1 cm ID pipe extended 0.6 m below the water's surface.

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TABLE 172. WATER JETS RESULTS SLICK CONVERGENCE TESTS (JO 56)

Boom L (m)	Nozzle I.D. (cm)	Tow speed (kts)	Press. (kPa)	Nozzle Angle in/fwd (deg)	Slick thk. (mm)	No. of nozzles on one side	Slick move (m)	Wave (m)	Orig width (m)	Final width (m)	Test no.
7	1.25	4	210	0/0	2.2	1	1.37	Calm	4.26	2.89	16
7	1.25	4	210	10/0	2.2	1	1.52	Calm	4.26	2.74	19
7	1.25	4	420	0/0	2.2	1	1.98	Calm	4.26	2.28	15
7	1.25	4	700	0/0	2.2	1	2.28	Calm	4.26	1.98	14
7	1.25	4	700	10/0	2.2	1	2.59	Calm	4.26	1.67	17
7	1.25	4	700	10/0	2.2	1	2.51	Calm	4.26	1.75	18
7	1.6	4	210	0/0	2.2	1	1.60	Calm	4.26	2.66	13
7	1.6	4	210	10/0	2.2	1	1.98	Calm	4.26	2.28	23
7	1.6	4	280	0/0	2.9	1	1.82	Calm	4.26	2.43	12
7	1.6	4	280	10/0	2.2	1	2.28	Calm	4.26	1.98	22
7	1.6	4	330	0/0	1.7	3	1.82	Calm	6.08	4.26	45
7	1.6	4	330	0/0	2.1	3	2.13	Calm	6.08	3.95	47
7	1.6	4	420	0/0	2.2	1	1.98	Calm	4.26	2.28	11
7	1.6	4	420	10/0	2.2	1	2.43	Calm	4.26	1.82	21
7	1.6	4	700	0/0	2.9	1	2.28	Calm	4.26	1.98	10
7	1.6	4	700	0/0	2.1	1	2.28	Calm	6.08	3.81	48
7	1.6	4	700	10/0	2.2	1	2.97	Calm	4.26	1.37	20
7	1.6	6	330	0/0	3.1	3	1.67	Calm	6.08	4.41	46
7	2.1	2	210	0/0	1.2	3	4.41	Calm	6.08	1.67	37
7	2.1	4	210	0/0	2.1	3	2.74	Calm	6.08	3.35	38
7	2.1	4	210	10/0	1.5	3	3.04	Calm	6.08	3.04	40
7	2.1	4	245	0/0	2.1	1	2.20	Calm	4.26	2.05	6
7	2.1	4	245	10/0	2.9	1	2.28	Calm	4.26	1.98	26
7	2.1	4	420	0/0	2.2	1	2.59	Calm	4.26	1.67	7
7	2.1	4	420	10/0	2.2	1	2.89	Calm	4.26	1.37	25

(Continued)

TABLE 172. (Continued)

Boom L (m)	Nozzle I.D. (cm)	Tow speed (kts)	Press. (kPa)	Nozzle Angle in/fwd (deg)	Slick thk. (mm)	No. of nozzles on one side	Slick move (m)	Wave (m)	Orig width (m)	Final width (m)	Test no.
7	2.1	4	560	0/0	2.2	1	2.59	Calm	4.26	1.67	5
7	2.1	4	560	0/0	2.1	1	2.59	Calm	4.26	1.67	33
7	2.1	4	560	0/0	2.1	1	2.59	Calm	4.26	1.67	34
7	2.1	4	560	10/0	2.2	1	2.97	Calm	4.26	1.29	24
7	2.1	4	560	10/0	2.1	1	2.89	Calm	4.26	4.41	35
7	2.1	4	560	10/0	2.1	1	2.89	Calm	4.26	4.41	32
7	2.1	4	560	20/0	2.1	1	3.20	Calm	4.26	1.06	31
7	2.1	4	560	20/0	2.1	1	3.04	Calm	4.26	1.21	36
7	2.1	4	590	10/0	1.6	1	2.59	Calm	6.08	3.50	42
7	2.1	4	590	10/0	2.1	1	2.74	Calm	6.08	3.35	41
7	2.1	4	590	10/0	3.0	1	2.13	Calm	6.08	3.96	44
7	2.1	4	590	0/45	2.1	1	2.43	Calm	4.26	1.82	71
7	2.1	4	590	0/45	2.1	1	2.59	Calm	6.08	3.50	70
7	2.1	4	590	10/45	2.1	1	3.65	Calm	6.08	2.43	S-7
7	2.1	4	590	20/45	2.0	1	2.74	0.5 HC	4.26	1.52	78
7	2.1	4	590	20/45	3.0	1	2.43	0.5 HC	6.08	3.65	67
7	2.1	4	590	20/45	2.1	1	2.74	Calm	4.26	1.52	76
7	2.1	4	590	45/45	2.9	1	2.28	Calm	4.26	1.98	80
7	2.1	4	590	45/45	3.0	1	Ind	0.5 HC	4.26	Ind	82
7	2.1	6	210	0/0	3.1	3	2.13	Calm	6.08	3.96	39
7	2.1	6	590	0/45	2.0	1	1.67	Calm	4.26	2.89	72
7	2.1	6	590	10/45	3.1	1	2.43	Calm	4.26	1.82	S-8
7	2.1	6	590	10/45	3.1	1	1.67	Calm	4.57	2.89	S-9
7	2.1	6	590	20/45	3.1	1	1.52	Calm	4.57	3.04	S-10

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TABLE 172. (Continued)

Boom L (m)	Nozzle I.D. (cm)	Tow speed (kts)	Press. (kPa)	Nozzle Angle in/fwd (deg)	Slick thk. (mm)	No. of nozzles on one side	Slick move (m)	Wave (m)	Orig width (m)	Final width (m)	Test no.
7	2.1	6	590	20/45	2.9	1	2.13	Calm	4.26	2.13	77
7	2.1	6	590	20/45	2.9	1	2.59	0.5 HC	4.26	1.82	79
7	2.1	6	590	20/45	2.1	1	Ind	0.5 HC	20	Ind	66
7	2.1	6	590	45/45	2.9	1	2.13	Calm	4.26	2.13	81
12	2.1	4	590	0/0	2.1	1	3.12	Calm	20	2.97	49
12	2.1	6	590	0/0	3.1	1	2.43	Calm	6.08	3.65	50
7	2.7	4	210	0/0	2.9	1	1.67	Calm	4.26	2.59	9
7	2.7	4	245	10/0	1.1	1	2.13	Calm	4.26	2.13	28
7	2.7	4	245	20/0	2.2	1	1.82	Calm	4.26	2.43	30
7	2.7	4	420	0/0	2.2	1	2.13	Calm	4.26	2.13	8
7	2.7	4	420	10/0	1.1	1	2.66	Calm	4.26	1.60	27
7	2.7	4	420	20/0	1.1	1	2.59	Calm	4.26	1.67	29
7	2.7	4	490	20/0	2.1	1	Ind	Calm	6.08	Ind	68
7	2.7	6	490	20/0	2.1	1	2.13	Calm	6.08	3.95	69
12	2.7	2	180	20/0	2.2	1	Ind	0.5 HC	6.08	Ind	63
12	2.7	4	180	0/0	2.3	1	2.89	Calm	6.08	3.20	57
12	2.7	4	180	10/0	2.1	1	3.20	Calm	6.08	2.89	59
12	2.7	4	180	20/0	2.0	1	3.35	Calm	6.08	2.74	61
12	2.7	4	180	20/0	2.1	1	Ind	0.5 HC	6.08	Ind	64
12	2.7	4	490	0/0	2.1	1	3.81	Calm	6.08	2.28	56
12	2.7	4	490	10/0	2.1	1	3.81	Calm	6.08	2.28	55
12	2.7	4	490	20/0	2.1	1	3.50	Calm	6.08	2.59	54
12	2.7	6	180	0/0	3.1	1	2.43	Calm	6.08	3.65	58
12	2.7	6	180	10/0	3.1	1	2.28	Calm	6.08	3.81	60
12	2.7	6	180	20/0	3.0	1	3.04	Calm	6.08	3.04	62
12	2.7	6	180	20/0	2.1	1	1.82	0.5 HC	6.08	4.26	65

(Continued)

TABLE 172. (Continued)

Boom L (m)	Nozzle I.D. (cm)	Tow speed (kts)	Press. (kPa)	Nozzle Angle in/fwd (deg)	Slick thk. (mm)	No. of nozzles on one side	Slick move (m)	Wave (m)	Orig width (m)	Final width (m)	Test no.
12	2.7	6	490	0/0	4.6	1	2.43	Calm	6.08	3.65	51
12	2.7	6	490	10/0	3.1	1	2.59	Calm	6.08	3.50	52
12	2.7	6	490	20/0	3.1	1	2.89	Calm	6.08	3.20	53
6	2.1	4	590	0/45	2.1	1	2.74	0.3 HC	4.57	1.82	18
6	2.1	4	590	0/45	2.3	1	1.82	0.6 HC	4.57	2.74	17
6	2.1	4	590	45/45	2.4	1	2.28	Calm	4.57	2.28	15
6	2.1	4	590	0.45	2.4	1	2.13	0.3 HC	4.57	2.43	19
6	2.1	6	590	45/45	2.2	1	2.43	Calm	4.57	2.13	16
9	2.1	4	590	0/45	2.0	1	2.28	Calm	4.57	2.28	20

EPA-287 (Cin.)
(4-76)

mathematics. Most of those assumptions were of a conservative nature so the resulting theoretical surface currents generated by the water jets were also conservative.

The work presented here can be used to develop an indepth theoretical analysis of the water jets. The approaches used by these first investigators are sound and produced results well within an order of magnitude from those derived from physical testing.

The work points out areas where modifications to the water jets might improve performance. The surface current which results from the water jets is not due in any great part to the mass flow of water from the jet but mainly from the entrained air.

JOB ORDER NO. 57 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	26-29 October 1979	
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817	201-321-6600
Device	Dispersant Spray Systems OHMSETT P.O. Box 117 Leonardo, NJ 07737	201-291-0680
Reports	Borst, M. Dispersant Application System for the EPA Research Vessel CLEAN WATERS. U.S. Environmental Protection Agency, Cincinnati, Ohio, 1980 (in preparation) (Ref. 4). Smith, G.F. Dispersant Application System for U.S.C.G. 32-foot Harbor Patrol Boats. U.S. Environmental Protection Agency, Cincinnati, Ohio, 1980 (in preparation) (Ref. 49).	

Description of Program

Several objectives were identified during this EPA sponsored project including a study on using OHMSETT for research and testing of dispersants and floating water-soluble hazardous materials, design and construction of dispersant application systems for both EPA and USCG vessels, and a study of the 5-bar gate's stability and mixing effectiveness. A report detailing alternatives and facility modifications necessary to expand OHMSETT capability to include dispersant and hazardous material testing was submitted to EPA. A 5-bar gate system was tested to determine effect of tow line length on mixing effectiveness and stability. A report is in preparation. Design, construction, and testing of a dispersant application system for the U.S. EPA vessel CLEAN WATERS was performed. An improved system was designed and fabricated to decrease weight and increase flexibility. Also designed and fabricated was a dispersant application system for a USCG 32-foot harbor patrol boat. These systems have also been tested. Reports and operation manuals for both the CLEAN WATERS and the USCG 32-foot boat dispersant application systems are in preparation. Contact Mr. M. Borst, U.S. EPA-OHMSETT, P.O. Box 117, Leonardo, New Jersey 07737 for additional information.

Conclusions

Three rows of vortex generators appear optimum. One row gives poor stability in waves and at higher speeds. Gates with more than three rows were not tested, but the added resistance caused by additional vortex generators undoubtedly will cause higher drag force with little change in mixing performance.

Use of different tow line lengths to control the mixing gates under tow is recommended. Data shows a 102 mm difference will be sufficient to give a four foot skid distance. Rope tied to the gate and the side of the towing vessel may be used to restrain the gate from skidding. The resulting force against the rope will keep the gate tracking straight and prevent excessive outward sway.

JOB ORDER NO. 58 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	9-16 May 1979	
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817	201-321-6600
Device	DiPerna Sweeper Global Oil Recovery Systems, Inc. Courthouse Square Toms River, NJ 08753	201-341-3600
Report	Breslin, M.K. Performance Tests of a Vacuum-Driven Skimmer, U.S. Environmental Protection Agency, Cincinnati, Ohio, 1980 (in preparation) (Ref. 9).	

Description of Program

This skimmer was the first vacuum-type skimmer to be tested at OHMSETT. The device proved the reliability and usefulness of employing an evacuated chamber to draw oil and water into the skimmer without mixing it. Near-pure oil could be pumped from the upper layer of the fluid in the skimmer after every test. The design as tested proved to be a low current, low wave, high recovery efficiency skimmer. The device was subsequently modified by the OHMSETT staff under the directions of the owners to improve its performance in waves and increase the fluid handling rate of the device. The skimmer was designed by Mr. James DiPerna, built by Brewer's Drydock Shipping Company, and is owned by Global Oil Recovery Systems, Toms River, New Jersey. The skimmer was one of the several small business skimmers tested at OHMSETT. An EPA report is in preparation.

Conclusions

The DiPerna Sweeper proved effective in recovering light and heavy oils at tow speeds up to 2.0 knots. Based upon samples taken at the oil offloading pump outlet the skimmer has the capability of offloading collected oil that is 95% or more free of water. This is due to the method of drawing oil and water into the skimmer without mixing them and offloading oil from top of the collected fluid and water from the bottom.

The best performance of the skimmer obtained during the two week test program is shown in Table 173.

TABLE 173. BEST PERFORMANCE DiPERNA SWEEPER (JO 58)

Tow speed	0.5 kt		1.0 kt		1.5 kt		2.0 kt		2.5 kt	
Dependent Variables	TE+	ORR*	TE	ORR	TE	ORR	TE	ORR	TE	ORR
Calm water	95.0	12.7#	96.2	26.3#	95.1	38.0#	75.3	40.2	33.2	22.1
0.3 m HC	44.1	5.3	72.8	19.4	46.4	18.5	27.3	14.6	ND	ND
0.3 m reg. wave	ND	ND	38.3	10.0	23.5	9.4	21.1	11.3	21.0	14.0

+TE expressed as percents, *ORR values were corrected to 12 mm thick oil slicks, ORR is in m^3/hr.

#One water discharge pump (70 m^3/hr) was used. All other tests used four pumps (125 m^3/hr total).

The discrete samples taken at the pump outlet resulted in RE values of 95.5% at 1 knot in calm water and 88% at 0.5 knots in the 0.3 m harbor chop.

The skimmer performed best in heavy oil in calm water. Waves caused drastic reductions in performance with regular wave head seas resulting in the poorest performance.

The greater the number of pumps removing fluid from the skimmer, the better the device performed. The primary objective to improve performance was to get as much of the oil slick into the device as possible and not worry whether some oil was discharged out the stern with the water.

The shovel-nose design of the skimming head and its attachment to the main body of the device via a large stiff hose was not conducive to optimum wave following. Overall performance in waves could be substantially improved with the proper skimming head and inlet hose.

The main portion of the skimmer was stable and generally unresponsive to waves. This was due to the deep, water-filled keel and the floatation chambers on both sides of the vessel.

JOB ORDER NO. 59 - U.S. ENVIRONMENTAL PROTECTION AGENCY, U.S. NAVY, U.S. COAST GUARD, U.S. GEOLOGICAL SURVEY, AND FISHERIES AND ENVIRONMENT CANADA

Dates
10-18 July 1979
6-10 August 1979
15-24 August 1979
15-23 October 1979

Customer
Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Naval Facilities Engineering Command
200 Stovall Street
Hoffman Building #2
Alexandria, VA 22332 202-545-6700

Civil Engineering Laboratory
U.S. Naval Construction Battalion Center
Port Hueneme, CA 93043 805-982-5435

Office of Research & Development
U.S. Coast Guard
G-DMT-4/TP54
Washington, DC 20593 202-426-1023

Technology Evaluation & Transfer Unit
Environment Emergency Branch
Fisheries & Environment Canada
Ontario, K1A 1CB, Canada 819-997-1788

U.S. Geological Survey National Center
U.S. Department of Interior MS620
Reston, VA 22092 703-860-7544

Devices
Sirene
Sapiens Company
23-27 Avenue de Neuilly
F75116 Paris, France (1)745.23.52

OMI Remote Controlled Skimmer
Oil Mop, Inc.
Engineers Road
P.O. Drawer P
Belle Chasse, LA 70037 504-394-6110

Troil/Destroil Boom-Skimmer
Hyde Products, Inc.
810 Sharon Drive
Westlake, OH 44145 216-871-4885

Versatile Bennett Arctic Skimmer
Bennett Pollution Controls, Ltd.
119 Charles Street

North Vancouver
British Columbia, V7H 1S1, Canada 604-929-5451

Report Lichte, H.W., M.K. Breslin, G.F. Smith, D.J. Graham, and R.W. Urban. Performance Testing of Four Skimming Systems. U.S. Environmental Protection Agency, Cincinnati, Ohio, 1980 (in preparation) (Ref. 29).

Description of Program

Sponsored by a group of U.S. and Canadian agencies known as the OITC, this program tested the four skimmers detailed below. Members of the 1979 OITC were the U.S. EPA, the U.S. Navy-NAVFAC and NAVSEA, U.S. Coast Guard, U.S. Geological Survey, and Environment Canada.

The first skimmer tested, the Sirene, designed by Sapiens, arrived from France after being successfully tested in open water at Marseilles and the Centre National pour l'Exploitation des Ocean's (CNEXO) test tank in Brest, France. The OHMSETT test program marked the first time that the entire device was tested in a tank. The device performed better in wave conditions than in calm water. This was due to the extreme amount of floatation provided by the inflatable freeboard of the device and the cup boom skirt which could be adjusted for different tow speeds. The cup skirt held the boom down against the water surface while the inflatable freeboard sections provided floatation. This gave the boom a self-stabilizing ability and held the oil inlet mouth at approximately the same depth throughout a test. The curvature of the inflated sections propelled any impacting wave away from the boom and thus kept the oil away from areas where it would normally shed beneath the boom. Modifications were suggested to the owner and designer based on using narrow slick tests which isolated areas of concern. It was proven that under certain tow speeds the efficiency of the skimmer could be increased fourfold by some minor modifications.

The second test device was a prototype OMI-Remote Skimmer made by Oil Mop, Inc. of Belle Chasse, Louisiana. Evaulation of the design concept, operational capability and performance were the primary objectives. The skimmer uses a continuous oil mop which adsorbs the oil, is stripped of the oil by a wringer, and placed on the oil surface again. The skimmer is controlled by using a remote unit on a cable tether. Analysis of the test data will provide clues to continued evolution of this concept for arctic use.

The Troil/Destroil system tests combined a barrier (Troilboom) and a skimmer (Destroil Model D5210 skimmer/pump). Several unique concepts are incorporated in the Troil/Destroil system to lessen oil shedding by the barrier and to increase versatility of the skimmer/pump. Testing was performed using the barrier with and without the skimmer/pump to determine barrier performance. The highlight of this program was the successful recovery of debris in addition to oil in testing the skimmer/pump.

The Versatile Bennett Arctic Skimmer was also tested. This skimmer is a remote control version of the Bennett Advancing Weir and Sorbent Belt Skimmer System.

An EPA report as well as a 16 mm film entitled, "600 Foot Ocean" are in preparation.

Conclusions

All tests under this heading are summarized with respect to the following areas:

1. Best Performance
2. Operating Limits
3. Mechanical Problems
4. Device Modifications

Sapiens Sirene

During the period 9 to 20 July 1979, 43 oil recovery performance tests were conducted with the Sapiens Sirene skimmer. A total of 31 tests were run with a high viscosity (Circo X heavy) oil and 12 tests with a medium viscosity (Circo medium) oil. This section summarizes the conclusions of the nine days of testing in four major areas.

Best Performance. Consistently, the highest values of RE, TE, and ORR were obtained during tow tests with waves. This result was surprising since the presence of waves generally causes poorer performance in oil skimmers.

Best skimmer performance (highest numerical results) achieved during these tests are presented, along with accompanying test conditions in Tables 174 and 175. Due to the skimmer's operating principle, the highest value of TE, ORR and RE did not occur under the same test conditions. Test oil logistics prevented the use of extreme amounts of oil which would have saturated the system over the entire tow test. Thus absolute maximums for ORR and RE were not determined.

It is worthy to note that no oil was lost due to splashover of waves. The cylindrical design of the continuous floatation elements caused the oil and water to be splashed away, in front of the boom. This was true even at the highest tow speed run in the roughest wave condition. Another reason for no splashover was the virtual absence of device heave with respect to the water's surface. The great amount of floatation coupled with the concave skirt design which tends to hold the device to the water's surface acted to maintain a relatively large, constant freeboard.

TABLE 174. BEST PERFORMANCE - SAPIENS SIRENE, HEAVY OIL (JO 59)

Performance parameter	Highest value	Tow speed (knots)	Wave H x L (m)	Test no.
TE	100%	0.75	0	1
RE	67.7%	1.25	0.7HC	27
ORR	50.8 m^3/hr	1.25	0.7 HC	27

TABLE 175. BEST PERFORMANCE - SAPIENS SIRENE, MEDIUM OIL (JO 59)

Performance parameter	Highest value	Tow speed (knots)	Wave H x L (m)	Test no.
TE	99%	0.75	All waves	36
RE	62%	1.25	0.7 HC	45
ORR	51.9 m^3/hr	1.25	0.7 HC	45

Operating Limits. Based upon both quantitative and qualitative results obtained from these tests, the operating limits of the Sirene skimmer appear to depend on the following three items:

1. Oil loss mechanisms which entrain oil into the water column and cause it to exit the confines of the system before it can be pumped out. Such losses occurred in three areas: (1) beneath the points of attachment between the side sections and the rear collection section, (2) beneath the outer large floats on either side of the oil/water inlet and (3) out the water outlet which is located beneath the oil suction box in the aft end of the device.

2. Limited pump capacity which allows the oil to build up in front of the oil inlet and therefore be subject to entrainment and shedding due to water flow beneath the oil.

3. The inability of oil to flow easily to the oil suction box after it enters the oil inlet. This allows the oil slick to be subjected to the water passing below it for a longer period of time. Entrainment and shedding of oil droplets is thus increased.

TE was not affected by slick thickness while RE and ORR were directly dependent.

Mechanical Problems. There were very few mechanical problems with the Sirene skimmer during the test period. Although the device was rather large, it was easily deployed into and rigged in the test tank without the aid of a crane or mechanical hoist. Six men carried the inflated sections to the edge of the tank and dropped them in the water.

A small gasket in the pump was found to have been installed incorrectly by the manufacturer. This was corrected and subsequent pump tests showed the effect was very minor. Towards the end of the test program a leak was discovered in the second stage floatation element. It appeared that the test oil had caused the adhesive at a seam to fail. A patch was made from excess material shipped with the skimmer and fastened to the fabric with an instant glue. No other leaks in the system were discovered. The owners are taking steps to improve the adhesive used in assemblying the Sirene.

Device Modifications. By distributing a narrow slick down the center of the device and holding it there using water jets, the rear oil collection section could be observed to function apart from the rest of the Sirene system. The data from these tests showed about a fourfold increase in system performance over previous tests which employed a system-wide oil slick. The system-wide slick was six times as wide and one sixth as thick as the narrow slick. This, plus observations, pointed to the most severe oil losses occurring at the attachment points of the side and rear sections and under the floatation elements on either side of the oil inlet. There was no noticable losses observed from under the 14.5 m long side floats.

In an effort to diminish the oil losses at the attachment points of the side and rear sections one length (3.3 m) of oil boom (Clean Water, Inc., Harbour Boom 0.6 m draft) was tied in front of each attachment point (tests 17, 18, 19 and 20). The upcurrent portion of the boom sections was secured to the side sections of the Sirene while the down stream end was secured to the rear section at the edge of the oil inlet. The purpose of the catty-cornered arrangement of the booms was designed to break up the severe change in angle betwen the side and rear sections into two smaller angles. Hopefully, this would stave off the oil shedding long enough to direct the oil directly to the oil inlet. The booms did not consistently improve the system's performance. Oil was seen flowing around the booms into the protected corner and shedding beneath the booms.

Oil Mop Remote

During the period 6-10 August 1979, nineteen oil pickup performance tests were conducted with the Oil Mop Remote Skimmer. A total of six tests were conducted with high viscosity oil and thirteen using medium viscosity oil.

The primary test objective was to generate design information for future construction of a larger version of the Oil Mop Remote Skimmer to be built for Arctic service in Canadian waters. The following are test conclusions relating to the design criteria for the larger skimmer.

1. At least three powered rollers must be provided to prevent slippage of the oil mop, especially when saturated with high viscosity oils.

2. The mop-oil slick contact length and rotational mop speed of the full-scale skimmer should be selected after conducting a series of oil mop saturation tests with the various viscosity oils expected to be encountered. The oil mop saturation times can be compared with various values of skimmer length divided by mop roller surface speed. Time available during the single week of testing was not sufficient to determine mop-oil saturation time for the two test oils. However, as an example of how performance is affected by mop-oil slick contact time, it showed that in tests with oils of 185 cSt viscosity, oil pickup performance (ORR) was unaffected by reducing the mop-to-oil slick contact length from 1.9 metres to 1.2 metres. ORR performance did fall off rapidly, however, when the contact length was reduced to 0.6 metres.

3. To maximize oil recovery rate the full-scale skimmer, hulls should be open on the sides to allow oil to enter from the sides as well as the front. This will increase the ORR by allowing more oil to come in contact with the tops of the oil mops which float above the water surface. The skimmer beam should be maximized to increase the oil mop surface area being laid down on top of the slick as it enters the front of the skimmer.

4. A positive displacement type offloading pump is necessary to ensure rapid offloading of collected oil over a wide oil viscosity range.

Best performance. Because the objective of these tests was to obtain design information for a larger unmanned Oil Mop Remote Oil Skimmer the highest numerical results obtained in these tests may not be the maximum obtainable with the full-scale Oil Mop Skimmer. The highest numerical values of the three performance parameters of TE, RE, and ORR for the present OHMSETT tests are summarized in Tables 176 and 177.

TABLE 176. BEST RESULTS - OMI REMOTE, HEAVY OIL (JO 59)

Performance parameter	Highest value	Tow speed (knots)	Waves H x L (m x m)	Slick thk. (mm)
TE	30%	0.5	0.3 x 4.2	9
RE	96%	0.5	0	6
ORR	2.6 m^3/hr	1.0	0	6

TABLE 177. BEST RESULTS - OMI REMOTE, MEDIUM OIL (JO 59)

Performance parameter	Highest value	Tow speed (knots)	Waves H x L (m x m)	Slick thk. (mm)
TE	43%	0.5	0.3 x 4.2	9
RE	93%	0.5	0.2 x 7.0	9
ORR	2.7 m^3/hr	1.0	0	9

Operating Limits. Based upon numerical and qualitative test results, the operating limits for this skimmer concept appear to depend upon two factors:

1. Maximize oil mop to oil slick contact area and rate.

2. Minimize slippage of oil-soaked mops through the squeezing roller assembly.

Regarding the first factor, it was noticed during stationary tests with medium viscosity oil that areas of clear water appeared under the point where the oil soaked mops were lifted out of the water at the stern of the skimmer. This indicated that the mops, at least on the side facing the oil slick, were fully saturated with test oil. The ORR performance of the device was seen to increase when the entire skimmer hulls were lifted clear of the water by an overhead crane, thereby exposing the tops of the floating oil mop to splashing contact with oil from the sides. In the full-scale device, the oil pickup rate (ORR) can be increased by maximizing the skimmer beam and opening the skimmer hulls along the length of the skimmer to allow oil to splash onto the mops from the sides.

Regarding the second factor, it is essential that future skimmers include three powered rollers instead of two as provided in the present Oil Mop Remote unit. Two rollers are needed to squeeze oil from the saturated rope mop. A third roller operating against one of the other two rollers, is needed to provide the mop tension to maintain the oil mop rotational speed. By visual observation, it was apparent that in almost all tests with heavy oil and some tests with medium oil slippage of the mops occurred at the two squeezing rollers. This resulted in the mops remaining on the oil slick after they had become fully saturated, reducing the net oil pickup per unit of time.

Mechanical problems. The following mechanical problems which limited the performance of the unit and it's deployment ease, were encountered during the test week:

1. Slippage of the oil-saturated mops while going through the squeezing rollers

2. Extreme changes of skimmer pitch attitude in the presence of waves as collected oil sloshed to the stern

3. Low thrust of the two electrically-driven propellers, causing the unit to be unmaneuverable in some wave conditions

4. Entanglement of the remote control umbilical as the unit was maneuvered along a 300 degree arc inside the boomed test area

5. Inability of the supplied submersible pump to offload collected oil fast enough to prevent its overflowing the stern of the skimmer

Testing was interrupted to correct the above mechanical difficulties, as time would permit.

Device Modifications. Slippage of the oil-soaked mops through the two-roller squeeze/rotational drive assembly reduced the oil pickup rate of the unit, especially in tow tests where, in some cases, the mop rotational speed dropped to ½ of the forward tow speed. A number of roller-squeeze tension adjustments were attempted but without effect. The problem was minimized to the extent possible during the tests by shortening the oil mops by 1.2 metres. This reduced the weight of oil-soaked mop which the squeeze/drive rollers had to pull from the skimmer stern.

The pitching action of the skimmer in waves was made worse by the fore and aft sloshing of recovered oil along the collection pan between the catamaran hulls. This was solved by the addition of a plywood transverse bulkhead amidships in the collection pan and by boring a second 5.1 cm diameter drain hole from the collection pan to the submersible offloading pump well to minimize the oil remaining in the collection pan.

The low thrust of the two props and the entanglement of the umbilical when attempting rotational maneuvers were not solved during the one week of testing.

The inability of the electrical onboard centrifugal pump to offload recovered oil was solved by connecting the suction of an OHMSETT-supplied 5.1 cm diaphragm pump to the discharge of the skimmer pump. Prior to the connection of the OHMSETT pump the inlet screen holes of the skimmer pump were enlarged from 0.6 to 0.9 cm diameter, but the pumping capacity with the 380 cSt test oil still proved to be insufficient to keep up with the rate of oil pickup by the mops.

All of the mechanical problems described above have been passed on to the equipment manufacturer, who was present during the entire week of tests.

Troil/Destroil

Best Performance. The Troil/Destroil Skimmer System was tested at OHMSETT 15-24 August 1979. The tests were conducted to measure the recovery performance of the combined boom and skimmer system and observe the interaction of the boom and floating skimmer. Table 178 shows the best skimmer performance for heavy and light oils. Skimmer performance parameters, Recovery Efficiency (RE) and Oil Recovery Rate (ORR), were at their highest when the preload oil volume was at the test maximum. Because of the size of the skimmer system it was necessary to preload the collection boom with oil for each test run. Tests were conducted with various preload volumes to detemine performance changes and guidance for operator control.

TABLE 178. PEAK PERFORMANCE - TROIL/DESTROIL SKIMMER SYSTEM (JO 59)

Performance parameter	Highest value	Tow speed (knots)	Preload m^3	Waves H x L (m x m)
HEAVY OIL				
RE	93%	0.75	3.785	0.26 x 4.2
ORR	20.9 m^3/hr	0.75	3.785	0.26 x 4.2
LIGHT OIL				
RE	91%	0.75	3.785	calm
ORR	23.8 m^3/hr	0.75	3.785	calm

Operating limits. The Troil/Destroil skimmer system, as tested, has the following operating limits:

1. The maximum towing speed at which the Troilboom can retain collected oil, without significant loss is one knot.
2. The maximum pumping rate of the Destroil skimmer pump is approximately 37.4 m^3hr.

At a boom towing speed of 1 knot the Troilboom lost oil at a rate of approximately 227 m^3/hr. When the towing speed was increased to 1.25 knots the oil loss rate increased to approximately 2268 m^3/hr. Oil losses were consistently observed to be the result of vortex shedding occurring near the side walls of the skimmer collection pocket.

The Destroil skimmer has an advancing screw pump which increases pumping rate as the viscosity of the pumped mixture increases. The maximum viscosity of the test oil was approximately 850 cSt.

The test series did not determine the pumping capabilities of the skimmer with higher viscosity mixtures. The skimmer pump was capable of ingesting a quantity of floating debris deposited during one of the test runs. The boom and skimmer system showed good wave following conformance in test waves up to 0.5 m irregular harbor chop. The independent towing bridle allowed the boom to maintain a relatively constant waterline while in the wave.

Versatile Bennett Arctic Skimmer

The Versatile Bennett Arctic Skimmer was tested at the OHMSETT test facility from 15 to 23 October, 1979. This skimmer is an air transportable remotely controlled version of the Bennett skimmer system. A larger Bennett skimmer, the MK 6E, was tested during the 1977 OHMSETT test season. The Arctic Skimmer is a prototype version developed for Environment Canada intended for use in cold weather. The Arctic Skimmer incorporates several improvements over the MK 6E Skimmer.

The objectives of the Arctic Skimmer tests were to observe skimmer operation in regards to operator control and mechanical performance. Skimmer performance was measured over several tank test conditions to gain operator control experience and to maximize skimmer performance.

The following conclusions were determined from the test series:

1. The skimmer can be controlled from onboard with the power pack mounted on the skimmer or operated remotely with the power pack connected to the skimmer through the hydraulic control lines. Several adjustable skimmer settings can be preset for remote skimmer operation.
2. Water jet nozzles can effectively concentrate and sweep oil into the skimmer at speeds from 1 to 4 knots in both calm and wave conditions.
3. Settings of the three adjustable skimmer doors are critical for maximum performance at each speed. A graph of skimmer door settings was developed from performance tests.

Best Performance. Tables 179 and 180 list the best skimmer performance for heavy and light oils respectively. In addition to regular towing tests with a 3 mm slick, several tests were performed to establish the maximum oil recovery rate (ORR) of the skimmer. In these tests at least 250 mm thickness of oil was presented to the skimmer and the skimmer then adjusted for maximum recovery rate.

TABLE 179. PEAK PERFORMANCE - BENNETT ARCTIC SKIMMER, HEAVY OIL (JO 59)

Performance parameter	Highest value	Tow speed (knots)	Waves H x L (m x m)	Slick thk. (mm)
TE	96.3%	2	calm	3.4
RE	85.0%	0	calm	250
ORR	2 m^3/hr	0	calm	250

TABLE 180. PEAK PERFORMANCE - BENNETT ARCTIC SKIMMER, LIGHT OIL (JO 59)

Performance parameter	Highest value	Tow speed (knots)	Waves H x L (m x m)	Slick thk. (mm)
TE	99.4%	1	calm	2.8
RE	97.4%	0	calm	250
ORR	1.9 m^3/hr	0	calm	250

Operating Limits. Each of the performance parameters can be maximized by the operator as follows:

1. To maintain high throughput efficiency, the skimmer should be operated at speeds not greater than 2 knots. The maximum safe skimming speed in calm water is 5 knots.

2. To maintain high recovery efficiency, a thick oil layer should be maintained at the collection belt. The belt should be raised even with the oil/water interface.

3. The oil recovery rate of the skimmer is limited by the maximum pumping rate of the skimmer pump. The actual rate will vary with the viscosity and discharge hose requirements. Maximum pumping rates observed for the 8 cm discharge hose with 4.5 m head was 23.6 m^3/hr.

The Arctic Skimmer was tested in waves 0.18 meter high by 9.4 meter long. The maximum height of wave in which the skimmer can perform is about 0.3 meter height, which is about the maximum depth of the bow door. As the skimmer is able to respond to longer period waves, the actual height of the wave can increase if the relative wave height at the skimmer mouth remains near 0.3 meter.

Mechanical Problems. No serious mechanical problems were encountered during the test series. Several minor problems occurred which were quickly corrected by the OHMSETT test crew, as follows:

1. Overheating of hydraulic fluid occurred after continuous operation. Additional temporary cooling was provided by hanging hydraulic hoses in the tank water.

2. Several hydraulic leaks occurred in the hydraulic hose bundle where hose couplings had loosened during shipment.

3. Lock nuts on the mid door adjustment screws loosened and jammed the opening mechanism.

JOB ORDER NO. 60 - U.S. NAVY

Dates	7-15 April 1980	
Customer	Naval Sea Systems Command Supervisor of Salvage Washington, D.C. 20362	202-697-7403
Device	Shell SOCK (Spilled Oil Containment Kit) Skimmer Shell Development Co. E-1340 Westhollow Research Center P.O. Box 1380 Houston, TX 77001	713-493-7094
Report	Lichte, H.W., M. Borst, and G.F. Smith. USNS Powhatan, SOCK Skimmer Offshore Tests, U.S. Environmental Protection Agency, Cincinnati, Ohio (in preparation) (Ref. 33a). Lichte, H.W., M. Borst, and G.F. Smith, USNS Powhatan, SOCK Skimmer Offshore Tests, IN: Proceedings of the 1981 Oil Spill Technology Conference, American Petroleum Institute, Atlanta, Georgia (Ref. 33b).	

Description of Program

Sponsored by Naval Sea Systems Command, preparations for offshore tests of an oil spill recovery device were started. Tasks performed included application for an Ocean Dumping Permit; observation of candidate test devices at the IXTOC-1 oil spill in Mexico's Bay of Campeche; procurement, transportation and storage of 50,000 gallons of crude oil test fluids; as well as preliminary engineering and test planning. Offshore tests were completed during the period 7-15 April 1980 using the Shell SOCK skimmer.

JOB ORDER NO. 61 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	30 April - 21 May 1979 8-12 October 1979	
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817	201-321-6600
Device	OHMSETT Wave Generating System	
Report	In-house report only.	

Description of Program

Characterization of the OHMSETT waves and wave generator operational limits is performed at the start of each test season. Wave heights, lengths, periods, and energy spectrums are determined for use by test planners. Additional importance was placed on the 1979 study due to the extensive wave dampening modifications made to the wave flap area and the beach. Data were also taken for research into the existence of standing waves in the test tank. Contact Mr. G.F. Smith, EPA-OHMSETT, P.O. Box 117, Leonardo, New Jersey 07737, for further information.

Conclusions

Regular waves can be created from 0.12 m (H 1/3) to 0.55 m (H 1/3) high. Wavelengths of regular waves vary from 0.97 m to 21.41 m. Regular waves that break and produce white caps were found at RPM's greater than 35 using 1.5 and 3 inch strokes.

Harbor chop waves ranged in height from 0.20 m to 0.69 m high. Breaking, harbor chop waves were found at four different stroke and RPM combinations.

JOB ORDER NO. 62 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates	16-20 April 1979 4-7 September 1979 1-4 November 1979
Customer	Oil and Hazardous Materials Spills Branch U.S. Environmental Protection Agency Edison, NJ 08817 201-321-6600
Devices	Murban Crude La Rosa Crude Fuel Oil, #2 Arabian Light Crude Arabian Heavy Crude Escravos Crude Nigerian Light Crude UK-Forties Crude Loreto Crude
Report	Smith, G.F. Weathering Tests for Selected Oils. U.S. Environmental Protection Agency, Cincinnati, Ohio, 1980 (in preparation) (Ref. 50).

Description of Program

Objectives of this study were to characterize the change in selected oil physical properties during exposure to both cold and warm weather, and observation of slick spreading and movement. Physical properties measured included specific gravity, viscosity, surface tension, interfacial tension and water content. Eight crude oils and No. 2 fuel oil were tested for weathering using thick slicks. Selected crude oils were tested for weathering using thin slicks. Selected crude oils and OHMSETT test oils were tested for slick spreading characteristics and movement caused by waves. A report is in preparation.

JOB ORDER NO. 63 -

Dates Not Tested

Customer
Oil Mop, Inc.
Engineers Road
P.O. Drawer P
Belle Chasse, LA 70037 504-394-6110

Device
OMI Boom
Oil Mop, Inc.
Engineers Road
P.O. Drawer P
Belle Chase, LA 70037 504-394-6110

JOB ORDER NO. 64 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 26-27 July 1979

Customer
Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Device Sirene Skimmer/Boom with Tramier Dispersant System

Report See Job Order Numbers 59 and 70.

Description of Program

See Job Order Numbers 59 and 70.

JOB ORDER NO. 65 - PETRO-FIBER, AB

Dates 27-31 August 1979

Customer
Petro-Fiber, Oljesanering, AB
Bokhallaregatan 35D
S-211 56 Malmo, Sweden 040-12-00-05

Device
Sorbent Distribution/Recovery System
Petro-Fiber, Oljesanering, AB
S-211 56 Malmo, Sweden 040-12-00-05

Report Confidential report provided to customer.

Description of Program

One of the first of several private user test programs performed at OHMSETT, this program was sponsored by Petro-Fiber Oljesanering AB of Malmo, Sweden under a

TYPING GUIDE SHEET
EPA-287 (Cin.)
(4-78)

TYPING GUIDE SHEET

grant from the Swedish government. A polyethylene/paraffin wax sorbent was tested along with a broadcasting system for placing the sorbent on the oil. Oil barriers with net skirts of 10, 20 and 30 mm mesh size were used, as well as a 12.5 mm mesh fishing net, to recover the sorbent/oil mixture. Results showed the utility of the sorbent in picking up oil and the feasibility of heating the sorbent/oil mixture to recover the oil. Recovery of the sorbent/oil mixture was demonstrated using both the barriers and the fishing net. Design changes to increase the rate at which sorbent can be broadcast were identified. Contact Dr. Bertil Brandin, Petro-Fiber Oljesanering AB, Bokhallaregatan 35D, S-21156, Malmo, Sweden.

JOB ORDER NO.66 - MARCO

Dates Not Tested

Customer Marine Construction and Design Co.
2300 W. Commodore Way
Seattle, WA 98199 206-285-3200

Device MARCO Class I Skimmer
Marine Construction & Design Co.
2300 W. Commodore Way
Seattle, WA 98199 206-285-3200

JOB ORDER NO. 67 - U.S. ENVIRONMENTAL PROTECTION AGENCY

Dates 30 July - 3 August 1979

Customer Oil and Hazardous Materials Spills Branch
U.S. Environmental Protection Agency
Edison, NJ 08817 201-321-6600

Device Oil Gelling System
University of Lowell
Chemistry Department
450 Aiken Street
Lowell, MA 617-452-5000

Report Letter report provided to EPA

Description of Program

The U.S. EPA sponsored testing of a vessel mounted system for gelling spilled No. 2 fuel oil. A Boston whaler was fitted with spray booms to distribute the gelling chemical mixture. Reaction chambers on each side of the hull added carbon dioxide gas to the oil/chemical mixture. Several tests were performed to determine practicability and optimum concentrations of chemicals and CO_2. Gelled oil was also squeezed to find out if oil and gelling chemicals could be reclaimed. Contact Mr. J.S. Farlow, U.S. Environmental Protection Agency, Edison, New Jersey, for additional information.

EPA-287 (Cin.)
(4-76)

JOB ORDER NO. 68 - U.S. COAST GUARD

Dates 1-15 June 1979

Customer
Office of Research and Development
U.S. Coast Guard
G-DMT-4/TP54
Washington, DC 20593 202-426-1023

Device None

Report None

Description of Program

This project consisted of providing support services to the U.S. Coast Guard in obtaining an Ocean Dumping Permit for tests of an open ocean skimmer. For further information, contact Mr. H.W. Lichte, U.S. EPA-OHMSETT, P.O. Box 117, Leonardo, New Jersey 07737.

JOB ORDER NO. 69

Not Assigned

JOB ORDER NO. 70 - SOCIETE NATIONALE ELF-AQUITAINE

Dates 24-26 July 1979

Customer
Societe Nationale ELF-Aquitaine
Centre Micoulau
Avenue Du President Angot
6400 PAU, France

Device
Sirene Boom/Skimmer with Tramier Dispersant System
See Job Order No. 59

Report All data provided to customer.

Description of Program

The customer, Elf-Aquitane of France, mounted a spray dispersant system on the floatation located directly behind the Sirene Skimmer/Boom inlet section. This system is designed to disperse any oil which the Sirene system failed to collect. Contact Mr. Bernard Tramier, Elf-Aquitaine, France, for further information.

JOB ORDER NO. 71 - MATTSSON PRODUKTOR, AB

Dates 12-15 November 1979

Customer

Mattsson Produktor, AB
P.O. Box 67
S-45101, Uddevalla 1, Sweden 0522-364-00

Device

Marine Emergency Skimming System (M.E.S.S.) "Walosep" Skimmer
Mattsson Produktor, AB

Report

Report provided to customer.

Description of Program

This program tested Mattsson Produktor, AB, of Sweden, M.E.S.S. skimmer system under a private user agreement. The skimmer is a unique offshoot of weir type skimmers. Performance data was obtained with several wave conditions, tow speeds, oil type and device operation modes. Additional information is available from Mr. Per Schwartzman, Mattsson Produktor AB, P.O. Box 67, S-45101, Uddevalla 1 Sweden.

JOB ORDER NO. 72 - GLOBAL OIL RECOVERY SYSTEMS, INC.

Dates

1 June - 30 October 1979

Customer

Global Oil Recovery Systems, Inc.
Courthouse Square
P.O. Box 1002
Toms River, NJ 08753 201-341-3600

Device

DiPerna Sweeper
Global Oil Recovery Systems, Inc.
Courthouse Square
P.O. Box 1002
Toms River, NJ 08753 201-341-3600

Report

None

Description of Program

Modifications were made to the DiPerna Sweeper at the request of Global Oil Recovery Systems, Inc.

JOB ORDER NO. 73 - CONSOLIDATED EDISON CO.

Dates

4-5 December 1979

Customer

Consolidated Edison Co. of New York, Inc.
Room 1026
4 Irving Place
New York, NY 10003 212-460-2327

Device

Fly and Bottom Ash from Coal-Fired Power Plant
Consolidated Edison Co. of New York

Report All data was provided to customer.

Description of Program

A private user agreement was executed with Consolidated Edison Company of New York to test the effect of dumping power plant coal ash at sea. Several tests were performed with fly ash to determine the rate of fly ash fall through the water, to determine whether any fly ash remained afloat after dumping and to provide photographic documentation of the fly ash behavior. Contact Dr. Han C. Moy, Con-Ed, 4 Irving Place, Room 1026, New York, New York 10003 for additional information.

APPENDIX A

TEST PLAN

This is the most important item necessary in testing. A thorough test plan will enable the tank user and OHMSETT personnel to spot problem areas immediately. The test plan will specify the demands to be put upon the facility and the system to be tested. By knowing what is expected, adequate preparations can be made to ensure problems are avoided.

A thorough test plan must include the following:

1. Objective - this contains the desired function of the device and what the tank user wishes to learn through testing at OHMSETT.

2. System Description - a list of individual components, with their size, weight, and function plus an explanation of the overall system operation.

3. Test Layout - the requested position of the bridges and the relationship of the system to them. The final layout will be dictated by the requirements and limitations posed by the tank.

4. Test Variables - by knowing which device parameters are instrumental in the recovery of the test fluid a table can be composed, listing the independent (i.e. tow speed) and dependent (i.e. recovery efficiency) variables.

5. Test Procedures - a step by step account of what will occur directly before, during, and directly after a test run. This will include shakedown runs to establish device settings and parameters.

6. Dependent Variables to be Calculated - a list of variables which will render a complete understanding of the system's performance under the different conditions imposed upon it and how they are to be calculated.

7. Test Matrix - this puts forth the days devoted to set up of the device in the tank, testing of the device, and removal of the equipment from the tank. If complex set-up and removal are involved, a description of the procedure to follow is needed. The actual test runs with the desired parameter settings are listed in two groups, a primary matrix and secondary matrix. The primary matrix contains tests absolutely essential to testing, while the secondary matrix contains tests which would give useful additional information on the performance of the system and which should be conducted if time permits. Not every parameter setting will have a value as optimum values for some settings will be determined in earlier tests for incorporation in the later ones.

8. Personnel Requirements - a list of personnel necessary to operate the bridges, test equipment and collect data should be given along with their duties and positions.

9. Material Requirements - the amounts and specifications for test fluids, film, chemicals, and for any materials needed for construction or modification.

10. Special Equipment Requirements - a list of machinery, instrumentation, containers, or other equipment which are required to perform the testing, including that being supplied by the tank user.

If the tank user is unfamiliar with the development of a test plan, the OHMSETT Test Engineer and Test Director will give assistance where it is needed. Operating personnel will critically review the user's test plan to suggest alternatives which may increase cost efficiency and optimize the test program.

TEST PLAN EXAMPLE

Objective

The MESAR Boom, developed by SLF, Incorporated, will be tested for performance at the Environmental Protection Agency's OHMSETT facility from 8 September to 11 September 1980. The objectives of the tests are to determine the system's capabilities to contain oil in various environmental conditions of waves and current velocity, to identify problem areas in the system design and to allow some measure of comparison of this system with other oil containment devices.

System Description

a. Length 61 m with 3 m reticulating sections

b. Net buoyancy 45 kg/m

c. Skirt draft 0.3 m

d. Towing arrangement-- tension concentrated near bottom

e. Ballast-- 1 cm cable

Test Layout

The system will be laid out in the tank to simulate as closely as practical operational conditions. The boom ends will be attached to the corresponding ends of the main bridge. The boom will then form a catenary configuration when under tow. The boom will be arranged in three sweep widths, if time permits.

Test Variables

The performance of the MESAR boom depends upon its ability to prevent splashover and shedding of oil beneath the skirt. At higher tow speeds, the boom may begin to plane, oscillate or submarine, allowing oil to escape. Based on this, test variables have been established and follow below. The independent variables are the parameters to be varied and the dependent variables are the performance parameters to be measured.

Independent Variables

1. Tow speed (0-6 knots)

2. Wave condition (calm, harbor chop)

3. Sweep width

Dependent Variables

1. Stable speed range

2. Ability to contain oil

3. Surface conformity

4. Tow tension

No tests will be performed with regular waves.

Test Procedures

After the boom is connected properly, a series of runs will be made to determine the maximum stability speed without oil. The speed will be brought up by increments of one-half knot until the boom becomes unstable. The speed will then be decreased until the boom becomes stable and increased again until instability reoccurs to confirm the previous run. This will be done for sweep widths of 9, 14, and 15 m if time allows. Identical tests will be documented by photography and visually by an observer located at the trailing end of the boom.

The amount of oil distributed will be 1 m^3 over a 4.6 m width at the beginning of each test. The speed will then be increased one-half knot increments until oil loss is noted. The speed will then be decreased below the oil loss speed and increased again for confirmation. This will be done for all three sweep widths, if the schedule permits.

After testing in calm water, the tests will be repeated in a harbor chop wave.

Dependent Variables to be Calculated

Most dependent values will be recorded by an observer, photographs and video equipment. The tow tension will be recorded on a strip chart using a load cell connected to the tow line.

Test Matrix

It is expected that installation and shakedown of the system will take one day and derigging will take one-half day. This leaves two and one-half days for actual testing. The primary test matrix shows the order and test conditions for the most important test runs and the secondary test matrix incorporates a wider sweep width.

Personnel Requirements

In addition to the Test Director and other personnel normally required to operate the tank bridges and equipment, approximately four persons will be required to conduct this test.

1. One observer at the trailing end of the boom.
2. One person to start strip chart recorder and video system.
3. One cinematographer for 16 mm movies from the bridge and other locations.
4. One photographer for 35 mm still photographs.

Material Requirements

This program will require 700 m^3 of medium oil and 500 m^3 of heavy oil.

Special Equipment Requirements

The following special equipment will be required for the tests:

1. A strip chart recorder to accept a 0 to 12 Volts or 0 to 1 millampere input.
2. A load cell with necessary wiring to measure 0 to 200 kg.

APPENDIX B

TEST DEVICE SUMMARY INDEX BY TYPE

DEVICE	JOB ORDER	PAGE
Booms		
Acme Products Co. O.K. Corral Boom	6	31
Bennett Pollution Controls, Ltd. Boom	7	50
B.F. Goodrich 18 PFX Sea Boom	6, 11, 21, 33	31, 58 104,55
Clean Water, Inc. Harbour Boom	6, 35	31, 192
Coastal Services, Inc. T-T Boom	6	31
Coastal Services, Inc. Sorbent Boom	41	207
Conwed Corp. Heavy Duty Sorbent Boom	41, 49	207, 244
Hydronautics, Inc. Air Jet Boom	31, 44	136, 254
Kepner Plastics Fabricators, Inc. Sea Curtain Boom	6	31
3-M Company, Inc. Type 270 Sorbent Boom	41, 49	207, 244
Offshore Devices, Inc. ODI-A, B, & C Booms	9	53
Offshore Devices, Inc. USCG High Seas Boom	11	58
Offshore Devices, Inc. USCG Skimming Barrier	34	162
Offshore Devices, Inc. SCOOP 250 Skimming Barrier	42	213
OHMSETT Water Jet Oil Herder	42, 54, 56	213, 253 286
Petroleum Association for Conservation of the Canadian Environment Boom	6	31
Pollution Abatement Associates Boom	26	122

DEVICE	JOB ORDER	PAGE
Seaward International Navy Standard Boom	26	122
Shell Development Co. High Current Boom	10	54
Slickbar, Inc. Mark VI Boom	6	31
Southwest Research Institute Boom	7	50
Ultrasystems, Inc. High Current Boom	15, 27	75, 122
Whittaker Corp. Expandi-Boom	6, 18	31, 83
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Acme Products Co. SK-39T Skimmer	6	31
Alsthom-Atlantic, Inc. Cyclonet D-050 Skimmer	8, 20, 32	52, 102, 138
Alsthom-Atlantic, Inc. Cyclonet 100 Skimmer	34	162
Anti-Pollution, Inc. Clowsor Skimmer	32	138
Bennett Pollution Controls, Ltd. Mark 6E Skimmer	32	138
Bennett Pollution Controls, Ltd. Arctic Skimmer	59	303
British Petroleum Co., Ltd. Komara Miniskimmer	6, 11, 18	31, 58, 83
Coastal Services, Inc. Slurp Skimmer	6	31
Douglas Engineering Skim-Pak Skimmer	46	240
Environmental Protection Machines, Ltd. Skimmer	46	240
Frank Mohn A/S Framo ACW-402 Skimmer	42	213
Global Oil Recovery Systems, Inc. DiPerna Sweeper Skimmer	58, 72	302, 320
Hyde Products, Inc. Troil/Destroil Skimmer	59	303
I.M.E. Kaiser OELA-III Swiss Oil Skimmer	6, 11, 35	31, 58, 192
JBF Scientific Corp. DIP 1001 Skimmer	7	50
JBF Scientific Corp. DIP 1002 Skimmer	8, 11	52, 58
JBF Scientific Corp. DIP 3001 Skimmer	19	99

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Lockheed HSORS Skimmer	4	21
Lockheed R2003 Skimmer	8	52
Lockheed 150F Skimmer	18	83
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MARCO Class I Skimmer	8	52
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Mattson Produktor, AB M.E.S.S. Skimmer	71	319
Morris Industries, Ltd. MI-2; MI-30 Skimmers	48	241
Ocean Systems, Inc. ORS-1000 Skimmer	4	21
Ocean Systems, Inc. OSI-125 Skimmer	8, 11	52, 58
Offshore Devices, Inc. USCG Skimming Barrier	34	162
Offshore Devices, Inc. SCOOP 250 Skimming Barrier	42	213
Oil Mop, Inc. Mark II-9 Skimmer	11	58
Oil Mop, Inc. ZRV Skimmer	29, 32, 42	132, 138, 213
Oil Mop, Inc. Remote Controlled Skimmer	59	303
Pennsylvania State University Oil Harvester Skimmer	13	73
Pollution Abatement Associates Sea Hawk Skimmer	18	83
Sapiens Co. Sirene Skimmer	59, 64, 70	303, 317, 319
Seaward International Streaming Fibers Skimmer	20, 36	102, 201
Shell Development Co. ZRV Sorbent Belt Skimmer	20, 44	102, 254
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Slickbar, Inc. 1" Rigid Manta Ray Skimmer	6, 11	31, 58
Slickbar, Inc. 1" Flexible Manta Ray Skimmer	6	31

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Slickbar, Inc. 0.5" Flexible Manta Ray skimmer	6	31
Slickbar, Inc. Aluminum Skimmer	6	31
Soviet Oil/Debris Skimmer	55	278
Tetradyne Air Jet Skimmer	23	113
Sorbents		
Coastal Services, Inc. Sorbent Boom	41	207
Conwed Corp. Heavy Duty Sorbent Boom	41, 49	207, 244
Dow Chemical Co., USA Imbiber Beads	35	192
3-M Company, Inc. Type 270 Sorbent Boom	41, 49	207, 244
Ocean Design Engineering Corp. MSORS Sorbent System	25, 28	121, 130
Petro-Fiber Oljesandering, AB Sorbent System	65	317
Petro-Trap Sorbent Wringer	49	244
Seaward International Re-usable Sorbent	11, 14	58, 74
Oil Spill and Slick Thickness Detectors		
Rambie, Inc. Infrared Oil Detector	37	202
U.S. Naval Research Laboratory Microwave Oil Detector	16	78
U.S. Naval Research Laboratory Infrared Oil Detector	20	102
U.S. National Oceanic & Atmospheric Administration Filter-Wedge Spectrometer	50	244
U.S. National Oceanic & Atmospheric Administration Closed-Circuit TV System	50	244
U.S. National Oceanic & Atmospheric Administration Barnes PRT-S Radiometer	50	244

DEVICE	JOB ORDER	PAGE
Chemicals		
3-M Company, Inc. AFF Foam	35	192
University of Lowell Oil Gelling Agent	39, 67	206, 318
Warren Springs Laboratory 5-Bar Gates	24, 38, 57	116, 205 301
Wave Measuring		
Stevens Institute of Technology Resistance Wave Probe	17, 40	83, 207
Stevens Institute of Technology Acoustic Wave Probe	40, 61	207, 315
Hazardous Materials Spill Responses--		
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Other		
Consolidated Edison Company of New York Fly Ash	73	320

APPENDIX C

TEST DEVICE ALPHABETICAL INDEX

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Alsthom-Atlantic, Inc. Cyclonet 100 Skimmer	34	162
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Bennett Pollution Controls, Ltd. Mark 6E Skimmer	32	138
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Coastal Services, Inc. T-T Boom	6	31
Coastal Services, Inc. Slurp Skimmer	6	31
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Consolidated Edison Company of New York Fly Ash	73	320
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Dow Chemical Co., USA Imbiber Beads	35	192

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Hydronautics, Inc. Air Jet Boom	31, 44	136, 254
I.M.E. Kaiser OELA-III Swiss Oil Skimmer	6, 11, 35	31, 58, 192
JBF Scientific Corp. DIP 1001 Skimmer	7	50
JBF Scientific Corp. DIP 1002 Skimmer	8, 11	52, 58
JBF Scientific Corp. DIP 3001 Skimmer	19	99
Kepner Plastics Fabricators, Inc. Sea Curtain Boom	6	31
Lockheed HSORS Skimmer	4	21
Lockheed R2003 Skimmer	8	52
Lockheed 150F Skimmer	18	83
LPI Corp. Model 33 Skimmer	46, 52	240, 252
MARCO Class I Skimmer	8	52
MARCO Class V Skimmer	22, 34	111, 162
Mattson Produktor, AB M.E.S.S. Skimmer	71	319
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Morris Industries, Ltd. MI-2; MI-30 Skimmers	48	241
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Offshore Devices, Inc. USCG High Seas Boom	11	58
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Petroleum Association for Conservation of the Canadian Environment Boom	6	31
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Pollution Abatement Associates Boom	26	122
Rambie, Inc. Infrared Oil Detector	37	202
Sapiens Co. Sirene Skimmer	59, 64, 70	303, 317 319
Seaward International Re-usable Sorbent	11, 14	58, 74
Seaward International Streaming Fibers Skimmer	20, 36	102, 201
Seaward International Navy Standard Boom	26	122
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Shell Development Co. ZRV Sorbent Belt Skimmer	20, 44	102, 254
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Slickbar, Inc. Aluminum Skimmer	6	31
Southwest Research Institute Boom	7	50
Soviet Oil/Debris Skimmer	55	278
Stevens Institute of Technology Resistance Wave Probe	17, 40	83, 207
Stevens Institute of Technology Acoustic Wave Probe	40, 61	207, 315
Tetradyne Air Jet Skimmer	23	113
Ultrasystems, Inc. High Current Boom	15, 27	75, 122
University of Lowell Oil Gelling Agent	39, 67	206, 318
U.S. Environmental Protection Agency Carbon Adsorption Trailer	5, 12	30, 73
U.S. Naval Research Laboratory Microwave Oil Detector	16	78
U.S. Naval Research Laboratory Infrared Oil Detector	20	102
U.S. National Oceanic & Atmospheric Administration Filter-Wedge Spectrometer	50	244
U.S. National Oceanic & Atmospheric Administration Closed-Circuit TV System	50	244
U.S. National Oceanic & Atmospheric Administration Barnes PRT-S Radiometer	50	244
Warren Springs Laboratory 5-Bar Gates	24, 38, 57	116, 205 301
Whittaker Corp. Expandi-Boom	6, 18	31, 83

APPENDIX D

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APPENDIX E

LIST AND DESCRIPTIONS OF AVAILABLE COLOR 16-mm SOUND FILMS

1. "Performance Testing of Selected Oil Spill Control Equipment: The OHMSETT Report" (1976). A 26-minute film documenting the use of EPA's OHMSETT test facility in evaluating selected booms and skimmers designed for rivers and harbors.

2. "Performance Testing of Spill Control Devices on Floating Hazardous Materials" (1977). This film depicts performance tests at OHMSETT on three floating insoluble hazardous materials--naphtha, octanol, and dioctyl phthalate.

3. "This is OHMSETT" (1978). A six-minute film describing capabilities of the OHMSETT test facility.

4. "Performance Tests of Four Selected Skimmers" (1978). This 20-minute film examines results of tests conducted at the EPA's OHMSETT facility on ocean-going oil skimming devices.

5. "Capturing Spilled Energy" (1978). A 25-minute film describing the evaluation of several offshore oil cleanup devices at OHMSETT.

6. "Handling OHMSETT Test Oil" (1979). Methods of test oil distribution, recovery, and refurbishing at OHMSETT are shown in this 20-minute film.

7. "OHMSETT Evaluation Tests: Three Oil Skimmers and a Water Jet Herder" (1979). A 20-minute film describing results of tests at OHMSETT on coastal and ocean-going oil skimming devices and a water jet device for controlling floating oil.

8. "Cleaning Up Our Act: EPA's OHMSETT Facility" (1980). A 15-minute film describing OHMSETT's role in the evaluation of oil spill cleanup equipment.

9. "600 Foot Ocean" (1980). A 20-minute news-report style film describing tests of four different oil skimmers at OHMSETT, including technical evaluation of test results.

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10. "USCG Zero Relative Velocity (ZRV) Oil Skimmer" (1980). This 18-minute film traces the development of the United States Coast Guard ZRV Oil Skimmer from hull and belt design to oil recovery tests at OHMSETT and includes open water shakedowns.

11. "Open Ocean Log" (1980). A 30-minute film describing five days of open sea evaluation of a large oil skimmer as performed by OHMSETT test personnel in cooperation with the U.S. Navy and the U.S. EPA.

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